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Systems Analysis Department
Annual Progress Report 1999

Edited by Hans Larsen, Charlotte Olsson and Leif Løvborg

Risø National Laboratory

March 2000

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Roskilde · Denmark

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Contents

Introduction

The activities of the department increased world-wide in 1999, and in particular the work for international organisations and the commercial activities for Danish and European industry was expanded. The year was characterised by consolidation following the organisational changes introduced by 1 January 1999. The two research programmes, Industrial Safety and Reliability, and Man/machine Interaction were merged to form a new programme: Safety, Reliability and Human Factors. In the autumn of 1998, an agreement was signed with the National Environmental Research Institute (NERI) on the establishment of a Centre for Analysis of Environment, Economy and Society. The centre comprises the Energy Systems Analysis programme and the Department of Policy Analysis at NERI. It is managed jointly by Risø and NERI and became operational from January 1999. Finally, 1999 was the year in which the new research programme Technology Scenarios became fully operational and obtained its first external funding.

The over-all objective of the research in the department is: development of technical-economic optimisation and risk management methods for complex industrial systems and energy systems, with emphasis on environmental considerations and human factors. The research activities of the department are undertaken within the following research programmes:

- *Energy Systems Analysis*, Frits M. Andersen
- *Energy, Environment, and Development Planning, UNEP Centre,* John M. Christensen
- *Safety, Reliability and Human Factors*, Nijs J. Duijm
- *Technology Scenarios*, Per D. Andersen.

Major events in 1999

A number of Scientific Advisory Panels have been established in order to strengthen the contact and interaction with the Danish and international scientific community and end users of the results, e.g. industry, authorities, and international organisations. Panels have been established for the UNEP Centre, the Technology Scenarios programme, and the new joint Centre for Analysis of Environment, Economy and Society. The panels have between 10 and 15 external members and are asked to give strategic advice on the directions for future activities as well as assess the quality and relevance of ongoing and proposed activities. All panels met in September or October and the last-mentioned panel also met for a start-up meeting in the spring. The contributions from the panels are regarded as very important. Further, the new research programme, Safety, Reliability, and Human Factors convened a one-day seminar and demonstration at Risø in February to present its activities to existing and potential collaborators and clients. The arrangement attracted about 60 representatives from Danish industry, consulting companies, and authorities.

The UNEP Centre is a collaborative activity established in 1990 between UNEP, Danida and Risø. The core activities of the centre are funded through two-year contracts. By the end of the year a new contract for 2000 – 2001 was agreed upon between the three organisations, providing the basis for continuation and further expansion of the centre activities.

The new Human-Machine Interaction Laboratory aims at facilitating the scientific understanding of usability aspects of peoples' interaction with computers and other technical systems. The establishment of the laboratory was finalised during the summer 1999.

By the end of the year the Technology Scenario programme was granted a project: "R&D Management Processes under Rapid Change (REMAP)", in collaboration with a number of Danish institutes and companies. The project is managed by the Copenhagen Business School, and is supported by the so-called SUE-programme under the Danish Research Councils. The research topics dealt with are of strategic importance for the new research programme.

Finally, in connection with the UNECE-EMEP taskforce on emission inventories and projections, Risø hosted a conference in June 1999. It was very successful with 120 participant from 35 countries.

In 1999, 61 per cent of the department's activities were financed through national and international research contracts, contracts with national agencies and international organisations, as well as with industrial companies and utilities. The remaining 39 per cent were financed by governmental appropriations. The total turnover of the department in 1999 amounted to approximately 52 mil. Dkr.

By the end of the year, the total number of employees in the department was 63. This included an academic staff of 57, namely, engineers, natural scientists, and economists as well as social and behavioural scientists, of whom seven were PhD students at various universities in Denmark and abroad and three were postdoc fellows. There were 6 secretaries and technical support staff. During 1999 four staff members earned a PhD degree.

Hans Larsen, Head of Department

Energy Systems Analysis programme

The aim of the research programme is to develop methods for analysing energy, environmental and economic issues, and the interactions between them, as well as new energy technologies and their adaptation to complex energy systems.

Effective from January 1999, Risø and the National Environmental Research Institute (NERI) established the Centre for Environment, Economy and Society. The centre is managed jointly by Risø and NERI and comprises the joint activities within the Energy Systems Analysis programme at Risø and the Department of Policy Analysis at NERI. The research areas covered by the centre are environmental economics, integrated environmental information systems, estimation and forecasts of emissions, and sector analyses within land use, transport, and energy. Guidance concerning priorities of research activities is given by a Scientific Advisory Panel, which held two meetings in 1999.

In 1999 the major activities within the Energy Systems Analysis programme can be grouped into the analysis of instruments and liberalised markets for energy, the development of methods for analyses and projection of energy consumption and emissions, and analyses of new technologies and their integration/adaptation into the energy system.

Within instruments and liberalised markets, in 1999 major activities were analyses of the transition from a monopolised to a liberalised market in the electricity sector and attendant hindrances for the energy policy as well as the survival of new renewable energy supplies (mainly wind turbines) in a liberalised market. In addition, the design of environmentally related markets, like those for green certificates, were studied. Also the effects of and potentials for instruments like CO_2 quotes, tradable permits, and Joint Implementation were analysed. In one project the European potential for using Combined Heat and Power (CHP) to achieve targets in the Kyoto Protocol has been analysed. In another project the effects of using European-wide CO_2-taxes and tradable permits to achieve the Kyoto targets were analysed. On the national scale a project on the distributive effects of energy and environmental taxes was initiated.

Concerning projections of energy consumption and emissions, the third version of INDUS was finalised and made use of to extrapolate the energy consumption of the industrial sector in Denmark. INDUS, an econometric satellite model to the macroeconomic model ADAM, determines the energy consumption by fuels and detailed industrial branches. In addition, emissions of CO_2, SO_2 and NO_X are linked to the consumption of the individual fuels and branches. Other important activities in 1999 were projections of emissions to the air from Danish sources of greenhouse gasses, ozone precursors, CO and SO_2, and the further development of environmental satellite models to ADAM. In 1999 work on satellite models to ADAM focused on the agricultural sector and related emissions.

Finally, in June a conference for the UNECE-EMEP taskforce on emission inventories and projections took place at Risø attended by 120 participants from 35 countries.

Within the analyses of technologies, in 1999 major studies have concerned electrical vehicles and their ability to increase the load flexibility of the electrical system, and the potential of using hydrogen as an energy carrier in the Danish energy system. Two important aspects of electrical vehicles and hydrogen are the flexibility of these technologies with respect to load management and the potential for reducing emissions in local and urban areas. Another study focused on the development of equivalent models of district heating systems. A major issue is how to give complex district heat networks a simplified representation that is manageable in a detailed simulation model and evaluate how good the approximation is.

Frits M. Andersen

Transition to liberalised power markets

The introduction of competition on the power markets has necessitated the creation of new competitive market structures, and a number of analyses of these structures have been undertaken by Risø. In the following the work carried out in 1999 in relation to two projects is briefly described.

A PhD project financed by Nordic Energy Research Program is carried out that analyses obstacles for energy policy and competition, and the survival of new renewable energy under competitive conditions. It is important to recognise and incorporate the hindrances in the liberalisation policy and analysis. Otherwise, purposes of the liberalisation and other energy policy goals may not be achieved.

Most of the liberalisation considerations in northern Europe have not taken into account that a number of imperfections will inevitably be present – at least during the transition period. These imperfections can be tradition-bound, technical or economic, and can also have political characteristics.

During the last ten years, the northern European countries have built up different organisations as well as legal rules for competition with roots in the political and technological national backgrounds of the liberalisation. These differences can be expected to create problems for integrating the countries in common energy markets with efficient cross-border competition.

Another potential market imperfection is the possibility for companies to exploit their market power and thereby obtain large margins. Also, the means to achieve political goals may hinder the desirable effects of the liberalisation. Many of the present energy and environment policies are designed for central planning. If the energy policies are not adjusted to a situation with competition, then they might not work as expected, thus hindering the goals of the liberalisation.

The survival and enlargement of renewable energy are playing an increasingly important role, which have low expectation under competitive conditions with all conventional technologies in a common market. Therefore, it is necessary to make particular arrangements for renewable energy, in order to ensure their survival in a liberalised environment – keeping in mind that these arrangements have to be designed in such a way that they do not hinder the goals of the liberalisation.

A number of analytical models have been developed within the PhD project in order to analyse most of the above-mentioned subjects. In addition, an econometric study has been carried out on data from the Nordic power exchange Nord Pool.

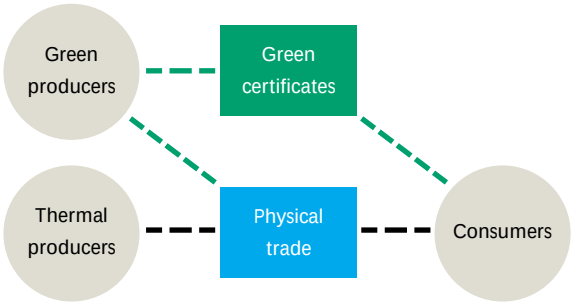
A pessimistic reading of the former sections could easily lead to the conclusion that competition in the energy supply industry in northern Europe is subject to a number of important obstacles and, therefore, not very likely to work. The analyses made in the PhD project provide a more balanced view of these markets. Several of the problems discussed must be considered as temporary. This is particularly the case with respect to the obstacles to cross-border competition that often are created by different national traditions.

However, several serious problems remain to be solved to guarantee workable competition in the future energy supply markets in northern Europe. One major obstacle seems to be market power from vertical integration of generation and distribution companies that is already considerable and is likely to increase due to take-overs. Another problem concerns the creation of suitable arrangements for the survival and enlargement of renewable energy technologies.

A comprehensive restructuring of the legislation for the electric power industry in Denmark was completed in 1999, including a proposal for developing a Danish green certificate market for electricity generated by renewable energy technologies. At present Risø is carrying out a project financed by the Strategic Environmental Program on the use of policy instruments in the long-term implementation of renewable energy technologies under free market conditions. In this project a number of issues related to the green market are being analysed, among these the optimal design of a green market and how prices are to be determined at such a market.

The main objectives of introducing a separate green electricity market in Denmark is to secure a cost-effective development of renewable energy technologies to help ensure that Denmark can comply with its commitments on GHG-reductions in the Kyoto-protocol. But equally important is the release of the Government from the burden of subsiding renewable technologies. In the green certificate model, the renewable production subsidy is converted from being paid out of the public budget to be paid directly by the Danish electricity consumers.

The main characteristics of the Danish proposal for a green certificate market are the following: (1) All consumers of electricity in Denmark are obliged to buy a certain share of electricity generated by renewable energy technologies, and (2) all renewable energy technologies will be certified for producing green electricity. Per unit of electricity produced (per MWh) they will get a green certificate, which can be sold to electricity consumers with the obligation to cover a certain share of their electricity consumption. The Danish Energy Authorities will determine this share, presumably for a number of years



in advance. At the end of each year a volume of green certificates corresponding to the quota will be withdrawn from the consumers by the authorities. According to the Danish electricity agreement a share of 20% of total electricity consumption has to be covered by renewables by the end of 2003. At present approx. 11-12% of total electricity consumption in Denmark is covered by renewables. The market will function solely as a financial market.

As part of the research project a small simulation model is being developed at Risø. The main objective of the model is to carry out different analyses of the green market, including a determination of future quotas, possibilities for banking and the price impact of the development of more cost-effective renewable technologies in the future

Presently the results from the project are being utilised in a dialogue with the Danish energy authorities and international research institutes.

Publications in 1999: 31, 32, 93, 94, 101, 102, 103
Poul Erik Morthorst and Klaus Skytte

Methodologies for externality assessment

The production of energy gives rise to different kinds of damage to the environment depending on the specific type of technology used. Externalities are the costs of these damages, which are not included in the price structure faced by the producer and the consumer.

During the past several years, external costs related to power production technologies have been calculated using various methodologies. Some studies have used a "top-down" approach, calculating the externalities in an aggregated way, typically at a regional or national level, while others are based on a "bottom-up" approach, giving site-specific estimates. The external costs may turn out to be very different for the same fuel cycle, depending on the methodology that has been used to assess the externalities. As a consequence of this, it seems rather important to be aware of the methodology that is made use of, which impacts are included, and the monetary values used in a given study before utilising the external costs from a specific study as a policy measure.

Two studies have been compared, the ExternE study and the New York Electricity Externality Study. The studies use basically the same methodology, a bottom-up methodology with a site-specific approach, i.e. it considers the effect of an additional fuel cycle, located in a specific place. The damage function approach is also used in both models for quantifying the impacts. This approach proceeds sequentially through a pathway in which emissions and other types of burdens, such as risk of accident, are quantified and followed through to impact assessment and valuation.

In both studies computer models have been developed, each of which assesses the environmental impacts and resulting external costs from electricity generation systems. The two models are based on the same concept, having an environment database at both a local and regional level including data on population, crops, building materials, and forests. Both models also incorporate air transport models, enabling local and regional scale modelling to be made. A set of impact assessment modules, based on linear dose-response relationships, and also a database of monetary values are included for different impacts.

As stated above, the models used are comparable. Nevertheless, the externalities calculated in the two studies for the same power plant differ by a factor five. The difference in the external costs in the two studies reflects differences in the impact assessment modules, differences in monetary values included in the two studies and differences in plant location.

Table 1 illustrates that human health impacts, including the greenhouse gas effect, are the dominant impacts when analysing externalities from energy production technologies. The reasons for the differences in the estimates of the effect on human health using the two models are shown in Figure 1. The latter illustrates four categories of differences in the estimates using the two models: Impacts, YOLL versus VSL (VSL is the value of a statistical life, while YOLL is years of life lost), dose-response (D-R) functions, and monetary values. In the figure the categories of differences have been included as

Table 1. Central estimates of external costs for a coal-fired plant

	The New York study EXMOD	The ExternE study EcoSense
Externalities	(mECU/kWh)	(mECU/kWh)
Human health	2.42	9.27
Mortality	1.71	7.97
Morbidity	0.70	1.30
Crops	0.002	0.134
Materials	0.10	0.22
Other impacts	0.32	0
Greenhouse gas effect	0	6.10
Total	**2.84**	**15.72**

changes in the two model lines in order to harmonise the externalities from the two models.

EXMOD starts with a central value of 2.84 mECU/kWh, while EcoSense starts at a value of 15.72 mECU/kWh (Table 1). The first change includes differences in impacts (greenhouse gases and chronic mortality not included in EXMOD and ozone impacts not included in EcoSense). The second change illustrates differences in using YOLL instead of VSL (YOLL depends on a number of factors, such as how long it takes for the exposure to result in illness and the survival time for the individuals). The third and fourth changes are related to the set of impact assessment modules used in the two models, including different dose-response relationships and different monetary values for the impacts.

After having adjusted for the above-mentioned parameters, there is a difference of 3 mECU/kWh in the two estimates. Most of this difference may be attributed to different locations of the plants, which affect population density and background level of emissions.

As illustrated here, it is important to be aware of not only the methodology that is made use of when assessing externalities, but also which impacts are included and the monetary values used in a given study before utilising the external costs from a specific study as a policy measure. A difference in the above-mentioned parameters may give rise to large differences in the external costs of the energy technologies analysed.

When politicians use externalities to assess the importance of different kinds of energy technologies, it is therefore quite important that they use external costs for the technologies based on the same approach, i.e. calculating the same impacts and using same monetary values and dose-response functions. This is also the case when externalities are used by the electricity utilities in order to choose between different technologies in capacity building; otherwise the comparison of the technologies may be based on incorrect assumptions.

Publication in 1999: 59

Lotte Schleisner

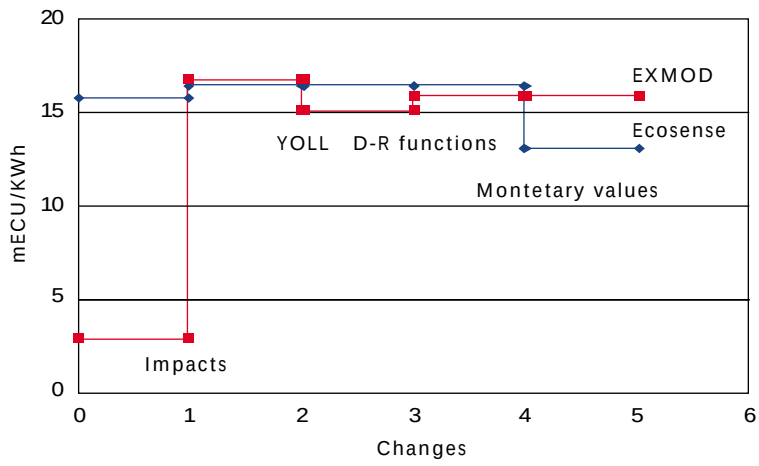


Figure 1. Differences in estimates of the effect on human health using the EcoSense and EXMOD models

Energy policy responses to the climate change challenge

The commitment of the European Union to reduce greenhouse gases requires analyses of the economic and technological options and the burden sharing among EU member states. During 1998 and 1999 Risø took part in a consortium of 9 European institutes co-ordinated by the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, on the Shared Analysis Project for the European Commission, Directorate General for Energy.

The overall objective of this energy analyses and forecast study, following the commitment in the Kyoto protocol, was to design a common framework to involve all Member States and the experts of industrial research groups. The aim was to analyse generic EU-wide issues important for energy policy, putting particular emphasis on world energy market trends and strategic energy policy responses to the Kyoto process, and to carry out quantitative analyses of energy trends and scenarios as inputs for discussion.

The project resulted in analyses of the issues and options for energy policy in the European Union over the next two decades assuming a future of low energy prices for fossil fuels and increasing energy import dependence for most European countries. The study was published in a Special Issue of *Energy in Europe*, December 1999 - Economic Foundations for Energy Policy – and 13 individual volumes.

Combined Heat and Power (CHP), renewables and energy efficiency

The main contribution by Risø has been the analysis of three main issues concerning energy policy responses to the climate change challenge:

- the penetration of CHP and renewables according to official objectives, focusing on infrastructure and institutions rather than technology
- the consistency of promoting CHP, renewables and energy savings at the same time.
- consumers' choices and priorities in a liberalised market

The contribution describes examples of policies in several Member States for these technologies with emphasis on CHP for both large- and small-scale district heating systems.

In 1994 less than 10 % of the electricity generation in the EU was by combined production with significant variations among Member States, ranging from more than 30% in the Netherlands, Denmark, and Finland to less than 5 % in the UK, France, Greece, and Ireland. The maximum technical potential of CHP has been assessed by different studies to be 40 % of the total electricity generation. This potential includes CHP for both industrial steam raising and district heating and cooling. Increased energy efficiency in industrial processes and space heating will reduce the technical potential for heat supply from CHP, which is dependent on the heat densities of the local heat markets. On the other hand, new technologies for CHP, in particular the combined cycle gas turbine (CCGT), has increased the efficiency of CHP technologies.

A given heat market will become a basis for a much larger generation of electricity, because of a very significant increase in the power-to-heat ratio (from 0.4 for traditional gas turbines to more than 1.0 for CCGT).

Past experience has shown that the penetration of CHP for district heating differs widely in the countries in north-west Europe, despite the lack of significant differences in climate and urban physical structure. The main explanation is the relative power of various institutions. A key factor for promoting CHP for district heating has been the influence of local government, while nationalised industries for electricity generation have been a major barrier.

An important issue was the consistency check for a massive introduction of CHP, renewables and energy efficiency at the same time as instruments to meet the Kyoto targets. Although there are examples of such inconsistencies from the past, experience also shows how these measures can be complementary or even synergetic. For example, the development of new built-up areas and urban renewal provides the best opportunity for implementing energy savings and district heating at the same time. The instruments to achieve such a synergy are physical planning and appropriate regulation of property developments.

Model analyses

The penetration of CHP technologies was analysed quantitatively using a traditional optimisation model approach for CHP regions – or stylised electricity generators with heat markets suitable for CHP – facing a competitive European market for electricity.

The most important distinction between generators is the access to heat from large-scale extraction-condensing power plants, which are part of the central electricity generating system. The results of the model calculations show that an initial capacity in 1995 has little influence on the technology choice. Under most assumptions the optimisation will choose the same technologies as in the regions with a planned development.

The figure compares the development of CHP on the basis of different scales of heat markets. Small-scale CHP will penetrate slowly where there is a local heat distribu-

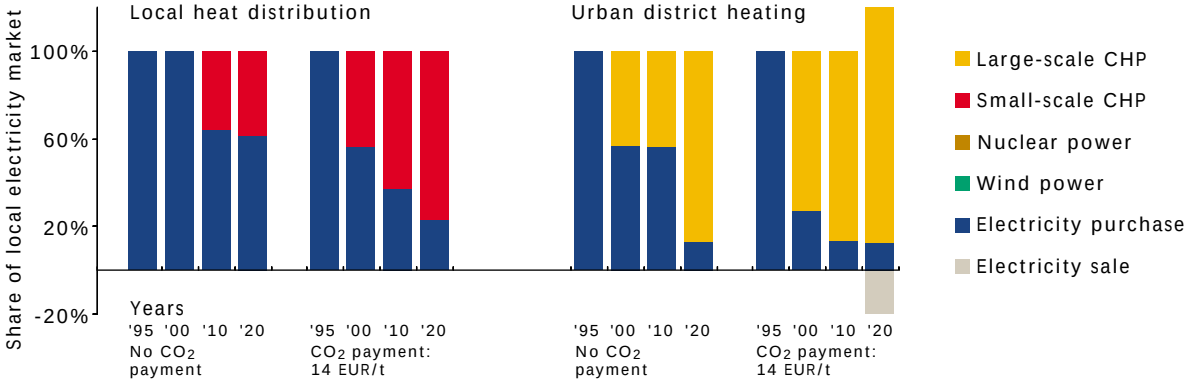


Figure 1. Electricity supply in potential CHP markets.

tion system. The introduction of CO_2 taxes or tradable emission permits with moderate CO_2 payments at a cost of some 14 EUR would lead to a faster penetration of small-scale CHP. In an interconnected urban district heating system where large-scale CHP is an available option, this technology seems to be dominant. In small local heat markets, where only small-scale CHP is possible, the technology choice is much more sensitive to variations in assumptions.

For a more thorough analysis of the prospects of penetration of CHP for district heating a broader modelling framework will be needed, able to address very different issues: These are (i) finding a more detailed description of urban structure at the local level based on Geographical Information Systems (GIS), and (ii) finding a description of the behaviour of agents in an imperfect international energy market, focusing on hedging against risks of price volatility, market failure of various, unexpected regulation and taxation, and regulation failures.

Publications in 1999: 15, 51, 74, 75
Poul Erik Grohnheit

Emission projections

In a project financed by the Danish Environmental Protection Agency and the Danish Energy Agency, projections were made of the emissions to the air from Danish sources of the greenhouse gases CO_2, CH_4 and N_2O, the ozone precursors NO_X, NMVOC, CO, and finally SO_2. The time period covered is from 1972, the first year detailed Danish energy statistics were produced, until the first commitment period (2008-2012) under the Kyoto Protocol to the Climate Convention. The purpose is to investigate whether the actions taken in the different sector plans are sufficient to decrease the emissions to the levels agreed upon in the Kyoto Protocol, as well as to the 2010 emission levels in the new ECE Protocol for SO_2, NO_X, NMVOC, and NH_3 signed 30th November 1999 in Gothenburg.

The projections are organised according to the sectors used in the Revised IPCC Guidelines for National Greenhouse Gas Inventories: Energy, Industrial Processes, Solvents, Agriculture, Land- Use Change, and Forestry and Waste. However, the report also gives a summary for each of the gases treated. The activity data were certified by key persons in each sector, and the implications of EU-directives and Danish decisions on activities and emission factors were incorporated.

Emissions from the energy sector are based upon data from the Danish Energy Agency with historic energy data until 1997 and the latest projection of the future primary energy consumption according to the follow-up on the Danish energy plan Energi 21. Emission factors used to calculate the emissions are based on the CORINAIR database.

In Energi 21 the goal is to reduce the emissions of CO_2 corrected for net electricity export and temperature by 20% of the 1988 level in 2005. The total emission in 2005 is calculated in the projections to be 50.3 Mt CO_2, or 1.5 Mt CO_2 more than the target. One reason for exceeding this target is that the goal for CO_2 emission in the Danish Action Plan for the Transport Sector is not reached. The target for the transport sector is that the CO_2 emission in 2005 should be the same as the CO_2 emission in 1988,

which was 10.2 Mt CO_2. However, the emission continues to increase, and is calculated to reach 12.6 Mt CO_2 in 2005, or 2.4 Mt CO_2 more than the transport target.

In the Kyoto Protocol the EU-countries all have an assigned amount in the first commitment period of 92% of the 1990 emissions. In the EU-Council decision on burden sharing among the EU-countries, Denmark must reduce its emissions by 21% in 2010 compared to 1990. The emissions to be reduced are the aggregate anthropogenic carbon dioxide equivalent emission of the greenhouse gases CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Figure 1 shows that in the projections the corrected Kyoto total reaches 62.6 Mt CO_2 eq. in the first commitment period, or 1.3 Mt CO_2 eq. above the target. However, as shown in Figure 2, without electricity export and temperature correction Denmark will emit 14.1 Mt CO_2 eq. more than the Kyoto target in the first commitment period. The reasons are a high electricity import in 1990 combined with an energy projection in the follow-up on the Danish energy plan Energi 21, which predicted an electricity export gradually increasing to about 17 TWh in 2010, corresponding to an annual emission of 12.8 Mt CO_2.

The emissions of HFCs, PFCs, and SF_6 are included in the totals in the two figures. However, as the total emissions of these pollutants never reach 1 Mt CO_2 eq. they are not visible in the figures.

The main part of the CH_4 emissions originates from animals in the agricultural sector. The future decrease in the CH_4 emission from agriculture is due to an increasing number of biogas plants. The second largest CH_4 emitter is the landfills. Emissions from landfills reached a maximum in 1994. Since then the emission has declined. This is due to the cessation of landfilling of combustible waste in 1997, the ageing of the landfills and the increasing number of landfill gas collection plants.

The N_2O emission in the projection decreases by about 20% from 1990 to 2010. The main reason is the impact of Danish action plans to decrease the use of nitrogen fertilisers with their environmental damage.

In the new ECE Protocol the targets for the 2010 emission levels are 55 ktSO_2, 127 ktNO_X and 85kt NMVOC. The Danish SO_2 emission has shown a drastic

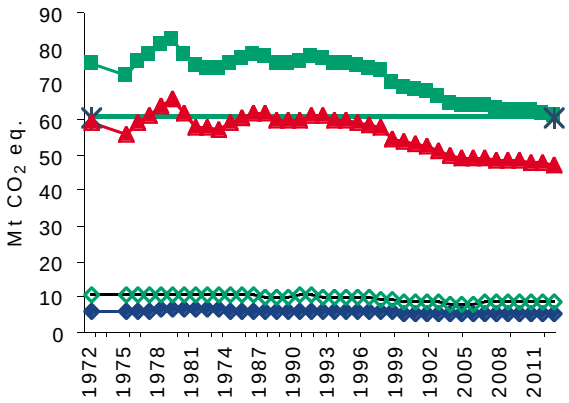


Figure 1. Total emissions of CO_2 equivalents from Denmark, corrected for electricity export and temperature.

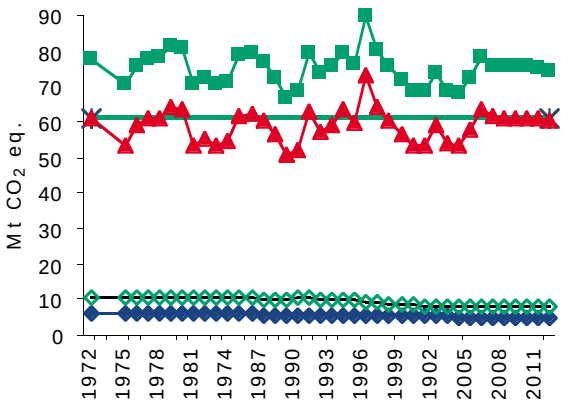


Figure 2. Total emissions of CO_2 equivalents from Denmark, not corrected for electricity export and temperature.

reduction from about 450 kt in 1980 to about 110 kt now and is projected to decrease below the ECE target to about 50 kt in 2010. Even with the new future NO_X emission factors for road transport, updated according to the lower cold start levels in the EURO I-IV norms, NO_X emission in 2010 is projected to be 133 kt. The main reason for being above the NO_X target is the large emission from the expected electricity export. The NMVOC emission in 2010 is projected to be 74 kt or well below the target – about half of this emission is expected to originate from the use of solvents.

In a project financed by the Danish Environmental Protection Agency the results of the projections were compared to the RAINS model calculations. There is generally good agreement, but in some sectors the reasons for differences in the emission calculations need to be clarified.

Publications in 1999: 48, 50, 63

Jørgen Fenhann

Planning and controlling decentralised CHP plants

The importance of Combined Heat and Power production (CHP) in existing power systems has become more evident in recent years. This is in particular true in Denmark, where the heat from CHP production is typically utilised for district heating (DH).

This utilisation results in a total efficiency of about 85–90%, whereas the efficiency of conventional power-plants is about 40%. In Denmark there has been a trend towards small decentralised CHP plants for the last five years or so. These plants typically produce power in the range 1–10 MW and provide DH to local, and in most cases relatively small, urban areas.

In order to analyse the aspects of CHP production in connection with DH and varying power prices, a PhD research project has been carried out at Risø in collaboration with the Technical University of Denmark (DTU). This research is financed mainly by the Nordic Council of Ministers and also by Risø and DTU.

In general terms, a typical decentralised CHP plant is fitted with a heat storage unit in the form of a hot water tank. Furthermore, many of the production units are based on piston engines, which are fueled by natural gas. In several of those cases, existing heat-only (boiler) plants have been converted to CHP plants, but the requirement that they deliver heat to DH customers remains unaltered. Thus, the main concerns when operating CHP plants are to deliver enough heat and sell power at the highest price possible. Figure 1 illustrates a simple CHP plant, where heat is withdrawn from the lubrication oil, cooling water and exhaust, and then delivered to a DH network.

The price of electric power varies, depending on the time of day and the current day of the week. This poses a problem for the plant operator, namely, that the heat demand must be fulfilled, but at the same time the production should take place when the price for power is high. This dilemma can be partly circumvented by using the heat storage unit. The storage unit stores excess heat when power production is profitable, and supplies heat to the DH customers when the power price is low. Therefore, the operator faces an optimisation problem, which is to determine when to operate the CHP plant, taking into account the storage contents and the uncertain future heat-load. This is referred to as a stochastic heat storage problem.

Aspects of the heat storage problem have been studied and solved in many different ways. Most of the work has been done by using deterministic optimisation proce-

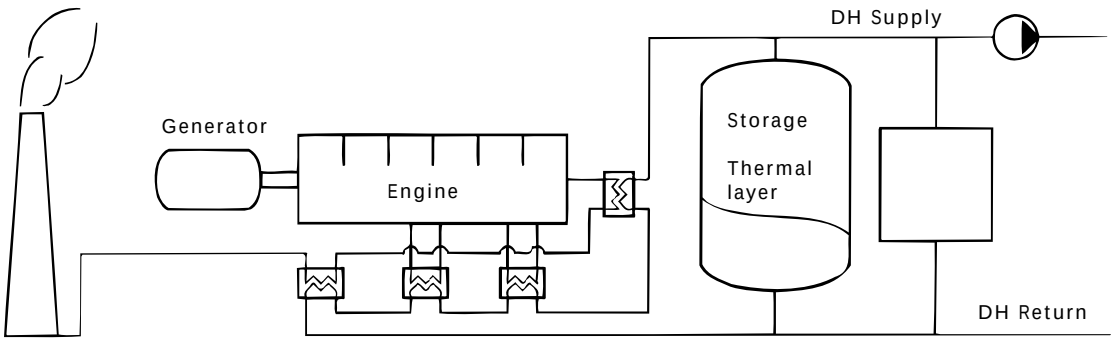


Figure 1. CHP plant with thermal storage, an engine and a boiler

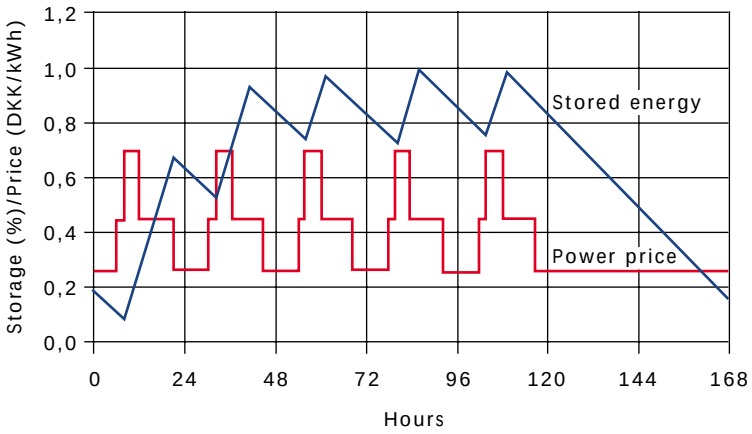


Figure 2. Optimisation results for one week in July 1997

dures, such as general nonlinear programming, mixed-integer linear programming and dynamic programming. When considering stochastic optimisation, the problem has been solved by using the so-called progressive hedging algorithm and dynamic programming.

In the research project, the stochastic heat storage problem is posed and solved, using a simple model of a small CHP plant as a reference. The optimisation is performed by using a stochastic discrete dynamic programming method, where the control decisions which are found are represented by boolean variables. This boolean structure determines which units should be operated during each time interval in the operational horizon. In most cases each unit is operated at the same level when running, which makes it sufficient to decide only if production takes place in the time interval, but not how much. A CHP plant located at Hvalsø, Denmark, has been used as a case study in order to obtain production data as well as some general knowledge of the decentralised plants. An analysis of the DH network of the plant has been carried out with the purpose of modelling the heat-load from the DH customers. This is done in order to obtain some insight into the varying heat-load properties, which is essential for predicting the required future production at the plant. Results from the case study show that the developed method is computationally very efficient, where a problem is solved with 168 (every hour in one week) boolean variables in a few seconds on an ordinary PC. Figure 2 shows how the storage is filled when the price is high and emptied when the price is low, indicating that the plant operation is optimal. Furthermore, the method seems to give robust results in different situations, i.e. under summer and winter conditions.

Publication in 1999: 98
Halldór Pálsson

Energy, Environment and Development Planning programme

The Energy, Environment and Development Planning Programme is the institutional framework for the UNEP Collaborating Centre on Energy and Environment. The core centre functions remain to provide technical and analytical support to UNEP's Energy Programme and contribute more broadly to UNEP's activities in climate change and in environmental and development economics. On a more general level, the centre supports UNEP in its function as implementing agency of the Global Environment Facility (GEF).

The UNEP Centre is a collaborative activity established in 1990 between UNEP, Danida, and Risø and governed by a Management and Policy Committee with representatives from the three organisations. In addition, the centre has an international Scientific Advisory Committee with high level experts from all developing regions and selected international institutions.

During 1999 the UNEP Energy Programme expanded its activities significantly through projects funded from bilateral sources and the GEF, and this has led to new activities as well as new functions for the centre.

A new focal area for the energy programme is to assist the financial sector to better understand the benefits of investing in sustainable energy. A new major initiative here is a GEF-funded project implemented jointly by the Energy Unit and the UNEP Centre to create an "investment advisory facility" for renewable energy and energy efficiency projects in developing countries and countries with economies in transition. The facility can provide financial institutions with services of technical experts to help in evaluating new investments in sustainable energy. The project was initiated early in the year and working relations have been established with a large number of banks, the first evaluation has been successfully concluded and several others are underway.

Another major new project prepared in the latter half of 1999 is the "African Rural Energy Enterprise Development" (AREED) programme, which will aim at increasing the capacity of the private sector in selected African countries to offer energy services using clean, efficient and renewable energy technologies. The project couples enterprise development services with modest amounts of start-up financing. The project is funded by the UN Foundation and will be implemented jointly by the Energy Unit and the centre together with E & Co, a US based non-profit venture-finance NGO and a number of African NGOs .

Preparations have begun for the 2001 meeting on Sustainable Energy of the Commission on Sustainable Development (CSD) with several inter-agency meetings and activities. UNEP and the centre have initiated several new activities, especially in the area of renewable energy technologies (RETs), as described in a later contribution to this report.

In the African region three-country pilot studies on promoting implementation of RETs have been under implementation throughout the year and preliminary findings were presented at national workshops in the fall. A new project for the Pacific Islands has recently been funded by Danida: "Capacity building on technological and economic integration of wind energy and other renewable energy technologies into the electricity systems of Pacific Island Countries". The project will be implemented in collaboration with the South Pacific Applied Geoscience Commission and the University of the South Pacific.

A general collaboration agreement has been signed with the Latin American Energy Organisation (OLADE) on the issue of sustainable energy development. The first joint project is part of the Caribbean Energy Action Programme, a long-term energy strategy promoted by OLADE together with the Association of Caribbean States, the Caribbean Community, and the Caribbean Energy Information System. The joint project focuses on national case studies for Jamaica and the Dominican Republic.

The UNEP Energy Sub-Unit and the centre prepared a new joint folder presenting the programme and the various centre activities. The redesigned centre newsletter also includes a presentation of the Energy Sub-Unit.

Climate Change Activities

A large number of activities have been undertaken in support of the Framework Convention on Climate Change (FCCC), as described in greater detail below.

The major new focus is on issues related to the Clean Development Mechanism (CDM), where several activities have been initiated covering the traditional UNEP and UNEP Centre areas of expertise:

Information & Awareness

- Two African regional meetings, both convened at UNEP Headquarters in Nairobi, involving key regional FCCC negotiators and individual regional experts.
- A centre-organised UNEP side event at COP 5 presenting the regional African programme on "Sustainable development and climate change finance"

Methodology development

- Participation in international expert meetings
- Establishment of an analytical work programme at the centre focusing on national decision-making frameworks, sustainability indicators, baselines assessment, and a project level analysis of institutional and financing aspects

Capacity building

- Pilot studies with four African countries (Gambia, Ghana, Uganda and Zimbabwe) co-ordinated by the national FCCC focal point and involving relevant public and private sector entities.
- Support to the establishment of a major inter-agency proposal for CDM capacity building

Another challenging activity in 1999 was the centre's involvement in the "National Communications Support Programme" which is implemented by UNDP in collaboration with UNEP funded by the GEF and several bilateral donors. During the year centre staff worked closely with both UNDP and UNEP on the implementation of the programme and participated by providing lecturers and resource persons in a number of regional training workshops on inventory assessment and abatement analysis. The programme continues in 2000 with an increased focus on direct assistance to selected countries, training and experience exchange.

The guidelines for mitigation analysis prepared under the UNEP/GEF project "Economics of GHG Limitations" were presented in a side event during the 10th meeting of the FCCC Subsidiary Bodies in June. The event was organised jointly with the FCCC Secretariat and copies of the guidelines were distributed officially to all delegations. The UNEP Centre also collaborated with the FCCC Secretariat on the compilation of non-annex I communications.

The involvement in the work of the Intergovernmental Panel on Climate Change (IPCC) remains very significant with four centre staff members participating as lead authors for the Third Assessment, one as coordinating lead author, and two staff members being lead authors for special reports on scenarios and technology transfer.

The long-standing centre activities related to mitigation analysis, methodology development, and capacity building continued under a number of different projects. These include support to national teams in Lebanon and Egypt with support from UNDP/GEF and in Columbia and South Africa with support from the German Technical Co-operation. Included also is the finalisation of the UNEP/GEF project Economics of GHG Limitations with publication of guidelines, 8 national reports and similar number of technical studies and handbooks.

The mitigation guideline activities were enhanced significantly for the transport sector through a project for the World Bank, where the centre prepared a set of internal World Bank guidelines for what is termed global overlays. This essentially provided a framework for ways to integrate climate change concerns into the preparation of transport sector projects.

In the transport area the UNEP Centre also organised and financed a workshop on "Sustainable Transport Initiatives in Developing Countries". The workshop was convened in El Salvador in July in collaboration with the national centre on appropriate technology – CESTA and the Ministry of Environment.

The workshop focused on exploring new policy options for urban transportation planning, which can assist developing countries meet the challenges of uncontrolled motorised transportation growth. Presentations focused on studies and case examples including transport planning practices, effective public transport management, etc. One of the specific outputs of the workshop was the establishment of an information exchange network to facilitate sharing of experiences and develop contacts.

John M. Christensen

International activities related to the Intergovernmental Panel on Climate Change

The methodological work of the UNEP Centre on climate change issues has been closely interlinked with international technical discussions and assessments conducted by the Intergovernmental Panel on Climate Change (IPCC). UNEP Centre staff have participated in several expert meetings and contributed as lead authors and convening lead authors in the development of special reports as well as the Third Assessment Report (TAR) of IPCC on Mitigation of Climate Change.

The UNEP Centre has participated in the development of The IPCC Special Report on Emissions Scenarios (SRES), which reports on new scenarios for GHG emissions and their socio-economic driving forces. These scenarios do not consider additional climate policy initiatives. UNEP Centre staff has led the scenario work on non-CO_2 GHG emissions from industrial production processes and emission sources in this scenario work.

After the completion of the IPCC's Second Assessment Report, many scenario analyses have been performed by research groups around the world, especially in the industrialised countries. These analyses have different objectives and apply very different methods. The IPCC has recognised the importance of long-term scenario analysis, and also acknowledged that the variety of studies makes a focused assessment for the Third Assessment Report a difficult job. In order to facilitate this job for the authors, an expert meeting on mitigation scenarios was organised 2-4 June 1999 in Copenhagen as a collaborative effort between the Danish Energy Agency and the UNEP Centre.

The special IPCC report on technology transfer considers how the economic and institutional policy environment on a global, regional, and national scale can be further developed to facilitate the technology transfer in particular to developing countries that meet national development priorities and help reduce greenhouse gas emissions (GHG). UNEP Centre staff has participated in the work on sectoral strategies and in the outline of the analytical framework.

Mitigation analysis

The IPCC TAR report generally covers all technology-related issues related to climate change mitigation as well as analytical framework and modelling issues drawing on multidiciplinary technical expertise in science, engineering, economics, and social science. Based on earlier IPCC work and experience from GHG limitiation work, the UNEP Centre participated in the TAR work on costing methodologies, policy instruments, and international climate change finance, as well as on the decision-making framework.

The work on cost concepts is a continuation of the Danish IPCC expert meeting on Mitigation and Adaptation Cost Concepts organised by the centre in June 1997. The TAR is now including a special chapter that outlines main cost definitions related to mitigation policies, which facilitate a transparent and consistent assessment of the many mitigation cost concepts included in economic and engineering models throughout the world. One of the special responsibilities of the

Overview of UNEP Centre IPCC work

IPCC Task	Specific issue	Main contributor from The UNEP Centre
Special Report on Emission Scenarios	Emissions from industrial processes	Jørgen Fenhann
Special Report on Technology Transfer	Analytical framework Sectoral strategies	John Christensen John Turkson
Expert Meeting on Stabilisation and Mitigation Scenarios	Programme committee and organisation	Kirsten Halsnæs
Third Assessment Report on Mitigation of Climate Change	Policy instruments Costing methodologies Decision-making framework	John Turkson Kirsten Halsnæs John Christensen Arturo Villavicencio

centre in this work has been to consider how specific issues of developing countries can be integrated into cost analyses.

Policy instruments for climate change mitigation is one of the focal issue areas of the TAR because the parties to the United Nations Framework Convention on Climate Change currently are working on the operationalisation of mechanisms for collaborative emission reduction policies. One of the more controversial discussion areas in this TAR chapter has been related to a comparative assessment of the advantages of project-based emission reduction mechanisms versus more general emission trading systems between countries. UNEP Centre staff have worked as resource persons on the perspectives of the capacity of developing countries to participate in such collaboration. The centre has finally worked on more general decision-making issues drawing from the experiences of analytical frameworks used by the centre.

Kirsten Halsnæs

Methodological frameworks: Economics of GHG Limitations

New methodological activity areas

The UNEP Centre has continued the work on methodological guidelines and their testing in studies on the Economics of Greenhouse Gas (GHG) Limitations. This work has recently involved the development of an extended framework for assessing indirect costs and benefits and the broader development impacts of GHG limitation policies. It involved as well the establishment of detailed guidelines for transport sector studies.

Extending the perspectives of the costing studies

Studies of GHG emission reduction policies have often focused on the direct costs of implementing specific projects or sector strategies. For the energy sector such costs are, for example, capital cost, land, fuel, operation and maintenance, and implementation. Direct cost estimates, however, do not fully reflect all the national social and economic development impacts that are important decision criteria for national governments.

The Economics of GHG Limitations project has therefore included a specific methodology work that has expanded the direct cost indicators with a number of additional decision criteria selected to reflect social decision criteria. These social criteria include employment impacts, income distribution, health impacts, local air pollution (SO_2, NO_X and particulates), and sustainability of energy resources. The work has been conducted as a collaboration between the UNEP Centre and professor Anil Markandya from the University of Bath in the UK.

The extended framework has been tested for a number of case studies including electricity saving options, biogas energy, solar water heaters, photovoltaics, wind turbines, and a number of other energy technologies. The case studies concluded that the inclusion of social cost aspects can have a major impact on the cost-effectiveness ranking of GHG emission reduction projects in developing countries. Such energy options as biogas plants and solar water heaters have been assessed to have significant social welfare benefits in cases were they generate increased employment, raise the income of low-income families and/or reduce local air pollution. Other GHG emission reduction options related to end-use energy efficiency improvement generate social benefits directly through fuel or electricity savings. These options, however, can be difficult to implement because they often rely on decisions by many individual agents. There is still very little information available about implementation policies for GHG emission reduction policies in developing countries, and this gives rise to a large uncertainty on mitigation costing results.

GHG emission reduction policies in the transport sector

The UNEP Centre has developed a methodological guideline for the Environmental Department of the World Bank on how global climate policy perspectives can be integrated into Bank transportation sector work. In World Bank terminology this policy concept is called global overlays. The methodological guidelines are described in a report with two volumes. The first volume focuses on cost effectiveness perspectives of global overlays and financial and practical issues related to policy implementation. The second volume is handbook material with economic, environmental, and technical concepts and assumptions.

The transport sector is the GHG-emitting sector that has experienced the largest growth in activity, and therefore in emissions, in the last decade (source), and this tendency will probably persist in the coming years. The implementation of global overlay policies in the transport sector therefore involves a number of new conceptual and practical issues, which are addressed in

global overlay guidelines. The basic analytical approach applied is cost-effectiveness analysis, where all technologies and policies are evaluated in relation to decision criteria that can include global as well as local policy priorities. The cost effectiveness approach can in practice be transformed into a project screening rule, where costs should lie below a given minimum cost "benchmark" for policies and options that are included in a more comprehensive cost-effectiveness study. The policy implication for global overlays in the transportation sector is that options supported according to the GHG emission reduction objective should have a cost per unit of GHG emission reduction that is considered as cost effective compared with other emission reduction options.

Transportation sector case examples

The global overlay analytical framework is illustrated in relation to a number of stylised case examples including: urban air pollution control in New Delhi, highway construction in China, road paving in Chile, LPG bus operation in Mauritius, and a vehicle maintenance programme in Pakistan.

The air pollution control case shows the potential trade-offs in local and global environmental benefits in relation to a stylised case for New Delhi. The air pollution control programme suggests that existing two-stroke three wheelers be replaced with options like four-stroke engines, a fuel/oil remix, an electronic ignition, engine rebuilding, a pumpless lubrication system, periodic I&M, phase out of old three-wheelers and conversion to CNG vehicles. Most of the technical options provide joint benefits on global and local externalities, except for the CNG vehicles, which reduce PM_{10} emissions but eventually can lead to increasing GHG emissions due to CH_4 leakages in the supply system. The magnitude of the local and global benefits, however, is very different. The benefit of reduced local externalities, which here are measured as change in PM_{10} equivalent emissions, are in total assessed to generate a benefit of more than $20 million. The global benefit of reduced GHG emissions, on the other hand, will be less than $1 million assuming a unit damage cost of $10 per tonne of carbon.

The case example of the World Bank highway project in China is one of a transportation activity that implies increased GHG emissions. The highway project is estimated to result in a GHG emission increase of 0.34 mill. t. C in 2010 compared with the business-as-usual case. The global overlay policy considered here consists of generating a decrease in the GHG emission intensity of the traffic through a separate World Bank activity that introduced energy-efficient diesel trucks to replace gasoline trucks.

The vehicle maintenance project in Pakistan is to offer joint local and global environmental benefits. It is based on a GEF-supported programme, including the establishment of engine tune-up demonstration and training centres in Pakistan in order to improve the fuel efficiency and thereby reduce the GHG emissions from existing vehicles. The programme is estimated to yield savings amounting to about 260,000 tonne CO_2 from 1996 to 1997, and will have a cost including that from GEF loan and maintenance of about $11.5 mill. It is, however, expected that the country will benefit from the project due to reduced fuel import by an amount of around $13 mill. per year, which makes the project very attractive from a local perspective.

Publication in 1999: 11

Kirsten Halsnæs

Clean Development Mechanism

The Kyoto Protocol contains commitments for the so-called Annex I Parties (mainly developed countries) to the United Nations Framework Convention on Climate Change (UN-FCCC) to reduce their total emission of six key greenhouse gases by an average of slightly more than 5%. At the same time, it provides a certain degree of flexibility as to how they will achieve this commitment: Article 6 of the Protocol allows them to acquire "emission reduction units" by financing emission reduction projects in other developed countries under a so-called Joint Implementation (JI) agreement; Article 12 establishes a "Clean Development Mechanism" (CDM), where emission-reduction projects promoting national sustainable development in Non-Annex I Parties (mainly developing countries) can be financed by Annex I countries who receive emission reduction units for doing so; and Article 17 sets up an international "emission trading regime" for parties to buy and sell emission credits.

The modalities and structures of all three mechanisms are still under negotiation and the Protocol has still not been ratified, so at present most activities focus on the

critical analytical, methodological and institutional issues. The timing is stated in the Protocol to give CDM the possibility of starting from 2000, provided agreement is reached among parties.

With its focus on sustainable development, CDM is one of the priorities for UNEP's activities on climate change and during 1999 the UNEP Centre has established a number of activities related to the critical issues mentioned above. Since the mechanisms eventually will compete or at least be interlinked the centre is also on a smaller scale participating in activities related to JI and emissions trading.

African regional programme

UNEP already in 1998 convened a number of regional workshops to discuss the CDM and the centre was responsible for the African meeting. This has been followed up by a regional Danida-sponsored UNEP programme under the heading of "Sustainable Development and Climate Change Finance". The programme focuses on CDM, but deliberately takes an integrated approach to the different financing sources available to countries.

The aims of the pilot-programme are to promote an improved understanding within the participating countries of how climate change financing mechanisms can be used to fund sustainable development projects, strengthen existing national capabilities for project development and analysis, and assess the capacity-building needs for undertaking the analytical activities required for preparing and implementing projects.

On the regional level, the programme will share the experiences from the pilot studies with other countries and facilitate regional co-operation and interaction in support of the FCCC negotiations.

National pilot studies have been established in Gambia, Ghana, Uganda, and Zimbabwe with the national FCCC focal points as co-ordinators and national teams involving the relevant sector institutions, finance and development planning, and the private sector.

To support the national studies the UNEP Centre works on three key analytical issues: national decision-making frameworks including sustainability indicators; approaches to baseline assessment; and tools for project identification, formulation, and design, including financing. The centre has no independent work on monitoring, verification, and certification, but activities in these areas elsewhere are being assessed, and the centre function here will be to adapt and communicate findings to the national teams.

As part of the regional programme, the centre, together with UNEP, convened an expert meeting in March in Nairobi where regional FCCC negotiators, policymakers, and researchers could discuss and develop positions on principles, modalities, rules, and guidelines for the CDM, and discuss the necessary capacity-building requirements

In order to continue the regional facilitation, an African consultation meeting was organised in early October, again at UNEP Headquarters in Nairobi, to provide a forum for key regional negotiators and experts to meet and discuss the proposals tabled for the 5th Conference of Parties (COP) later the same month. The report of the meeting subsequently formed the background for the regional negotiation position at COP 5. UNEP and the centre organised during COP 5 a so-called side event, where the regional programme was presented to interested delegates. This seminar was opened by UNEP's executive director Klaus Töpfer.

Inter-agency programme on CDM capacity building

The Climate Change Secretariat (CCS) early in 1999 initiated a co-ordination effort with a number of key UN agencies (UNCTAD, UNDP, UNEP, UNIDO) to ensure that activities related to the Kyoto mechanisms were better co-ordinated among agencies and information provided to the FCCC Parties.

In the interagency process it became evident that a

Figure 1. Workshop participants discussing the link between the CDM and technology transfer

joint effort would be desirable to ensure adequate, timely, and co-ordinated action. The effort was quickly oriented towards developing a joint programme for capacity building, which initially would focus on CDM due to the envisaged early start of the this mechanism as stipulated in the Protocol.

With its experience in both analytical and capacity building issues in mitigation, the UNEP Centre was asked to be part of the UNEP team. Considerable effort went into preparing a proposal for COP V, where it was formally circulated to Parties and presented in a special CCS-organised side event. The centre represented UNEP in the side event and together with UNEP staff took part in all the project negotiations.

The COP generally endorsed the programme and the proposal has been submitted to interested donors. UNEP has a leading role on the analytical activities and co-ordination of the envisaged national pilot studies, and the centre will support the implementation of UNEP's components. The activities build on the experiences from the regional African programme described above and will establish national studies also in Asia and Latin America and involve significant participation of regional and national experts from all participating regions. The programme involves close collaboration with especially both UNIDO and UNCTAD.

In 1999, the UNEP Centre undertook a desk study for the Asian Development Bank estimating the potential global supply and demand for GHG abatements in the First Commitment Period in terms of the Kyoto Protocol commitments of Annex B Parties. The results of the study were presented at a regional workshop in Bangkok in October after a formal review process. The study and the workshop presented a very interesting opportunity to extend the CDM-related activities beyond the activities in the African region.

The national participants from 15 countries expressed during the workshop a strong need for activities at the national level. Initially the interest is directed towards promoting increased awareness and understanding of the CDM, but subsequently it may move towards building capacity in relevant institutions. These activities are under discussion with UNEP's regional office in Bangkok.

The study estimated that the total CO_2 emissions from fossil fuels and industry in developing countries, according to recent IPCC scenario work, will range from 5,200 mill. t. C to 4,000 mill. t C in 2010. A number of observations were also made on the marginal costs of GHG emission reduction projects in developing countries, based on co-ordinated study efforts for developing countries conducted by UNDP, the Asian Development Bank, and UNEP. These studies concluded that GHG emission reductions in the energy sector in the order of magnitude of 10% to 15% of future baseline emissions can be achieved at a cost below US$ 25 per tonne of CO_2 (corresponding to a cost below about US$ 91 per t. of C). If the costing results of these studies are applied to the total future GHG emissions in developing countries, it implies that the potential for low-cost GHG emission reduction projects in developing countries will be between 400 mill. t C and 520 mill. t C in 2010 potentially, if it is assumed that 10 % of the GHG emissions will be supplied to a global market in 2010.

The study, therefore, concluded that the demand for CDM projects supplied by developing countries will most likely not be very large compared with the total future GHG emissions in these countries assessed for the developing countries as a whole. Even in the extreme case, where CDM projects are assumed to cover a large part of reduction commitments in 2010, these projects will still constitute a relatively small fraction compared with total future CO_2 emissions from fossil fuels and industry according to the scenarios for developing countries developed by global energy models.

Publications in 1999: 10, 42, 92

John M. Christensen

Renewable Energy Technology projects

The increased use of renewable energy is not only a way of meeting the growing demand for energy, but it also contributes to all dimensions of sustainable development, particularly in developing countries, by providing additional economic, social and environmental benefits. Therefore, one of the challenges for energy policy is to ensure that environmentally sound technologies, including renewable energy technologies (RETs), have a fair opportunity to compete for resources required for the provision of energy services. In many cases, renewable energy is already the most economical solution, for example, in providing energy to remote and widely dispersed rural populations that are not connected to the electricity grid. The underlying thrust of these projects is

the analysis of the opportunities and major barriers to the adoption of RETs and how these barriers can be removed for modern/commercial energy from renewable energy sources to be an important part of the energy mix in developing countries.

The UNEP Centre is involved in the following RET projects:

Implementation of RET projects – opportunities and barriers

This Danida-funded UNEP project is being implemented in three African countries: Egypt, Ghana, and Zimbabwe. The overall objectives of the project are: (i) to improve the knowledge and skills of project partners to identify and analyse main barriers to the adoption of renewable energy technologies to meet national energy needs, and (ii) to strengthen institutional capacity for analysis and implementation of RET projects in participating countries. The project uses case studies of renewable energy projects that have been implemented to analyse the reasons for success or failure of these projects or technologies.

The first of the two national workshops has been organised in all countries where:

- rationale of the projects was introduced to all stakeholders including policy makers, private sector institutions (sellers and users), NGOs and researchers;
- findings of preliminary analysis of barriers to adoption of different RETs were presented and discussed;
- relevant RETs such as photo-voltaic (PV) systems, solar crop dryers, mini-hydro technologies, wind turbines, and biogas technologies, have been selected for detailed analysis in each participating country;
- advisory committees have been set up in each country to provide technical backstop for the local experts working on the project.

Mid-term reports have been submitted, which provide an overview of national policies on renewable energy and the findings of the preliminary analysis.

Redirecting commercial investment decisions to cleaner technologies – Investment Advisory Facility

This GEF-funded UNEP project aims at influencing commercial investment decisions by providing specialised advisory services to development and commercial banks for assessing projects involving energy-efficient or renewable energy technologies (EE/RET). As the risks of these technologies tend to be overestimated, the project intervention is expected to make successful a number of proposals that otherwise would be dropped by the borrowers, as a measure of the "additionality" of the project.

The project is expected to have the following results: additional lending directed at EE/RET; upgrading of skills in loan officers in developing country financial institutions; and reduced emission of greenhouse gases.

The main involvement of the UNEP Centre is in the evaluation of proposals sent by the invited banks to obtain advisory services. The centre is also collaborating with UNEP and CANMET Canada in the adaptation of a software package for the quick evaluation of EE/RET by loan officers.

Four of the five proposals evaluated during 1999 were approved for the advisory services: a wind park in Ghana, a sustainable wood supply for a salt refinery in Tanzania, energy-efficient coffee bean drying using process wastes in Costa Rica, and fuel switching and implementation of a cogeneration plant in the Slovak Republic.

Upgrading of the RETScreen model

A memorandum of agreement has been signed between UNEP and CANMET Energy Diversification Research Laboratory (CEDRL) in Canada. CEDRL has developed the RETScreen model as an aid in RET project evaluation and to help the user prepare pre-feasibility studies for RET investment. Based on the experience with the Greenhouse Gas Costing Model (GACMO), the centre will help CEDRL introduce a greenhouse gas emission facility into the model, which will allow the user to prepare an estimate of the greenhouse gas emissions avoided by the RET project. The international appearance of the model will also be improved, and UNEP will help CEDRL to explore potential funding sources for increasing the number of technologies treated from the present eight: wind, small hydro, solar water heating, photovoltaics, solar air heating, passive solar heating, small biomass heating systems, and heat-pumps. The goal is also to include energy efficiency options in the model.

Capacity building on technological and economic integration of wind energy and other relevant renewable energy technologies

During 1999 the UNEP Centre has led the design of a new Danida-funded UNEP project directed to strengthen the capabilities of Pacific Island Countries to integrate wind and other forms of renewable energy into their electricity systems. The Wind Energy & Atmospheric Physics Department of Risø and the South Pacific Applied Geoscience Commission contributed in the development

and will be involved in the implementation of the project.

It is expected that the project will prepare material for a graduate level course and train researchers at the University of the South Pacific, as well as build wind energy development plans and prepare an international workshop.

The initiative has been approved in December 1999, and a first mission to the region is scheduled for the first quarter of 2000.

John Turkson and John M. Christensen

Technical support to UNFCCC National Communications

The National Communications Support Programme (NCSP) aims to enhance the capacity of non-Annex I parties to prepare their National Communications to the UNFCCC. The Programme is run by UNDP and UNEP, in co-operation with UNFCCC. Core funding was provided by GEF, with complementary financing from the European Commission, Finland, Denmark, and Norway.

The NCSP has three components: a Support Unit based at UNDP in New York to co-ordinate the activities; technical assistance to provide backstopping and support, and up to thirty regional and thematic workshops for national teams working on the communications.

The UNEP Centre is responsible for technical backstopping to UNEP and UNDP on the organisation and presentation of workshops, and for direct assistance to countries on technical issues related to their communications. This is a rather challenging responsibility given the broad range of issues that countries should address in the communications.

Non-Annex I parties are committed to develop, periodically update, and communicate to the UNFCCC national inventories of all anthropogenic greenhouse gases not controlled by the Montreal Protocol. Emissions by sources and removals by sinks should be quantified through consistent methodologies previously agreed upon, in order to enable a further comparison. Other elements to be included are a general description of steps taken or envisaged to implement the convention and any other information relevant to the achievement of its objective.

Developing countries can optionally include national and eventually regional measures to mitigate climate change (by reducing emissions and enhancing sinks of greenhouse gases), measures to facilitate adaptation to climate change in vulnerable areas, and proposals for financing projects on mitigation and adaptation.

The programme raised high expectations among non-Annex I countries, as indicated by the level of attendance to the workshops and the discussions held within them. In the initial stage of NCSP, however, minor use was made of the direct assistance to countries that the programme can offer on specific technical issues.

During 1999 the UNEP Centre has participated in the preparation and presentation of workshops on inventories in Nairobi, Azerbaijan, and Barbados, workshops on mitigation in Guatemala, Côte d'Ivore, and Georgia, and a combined workshop on inventories and mitigation in the Philippines.

The centre's involvement in the workshops included designing agendas, providing technical guidelines, facilitating and participating in the discussions, and encouraging participants to exchange national experiences.

On the inventory side, the centre provided hands-on

Figure 1. Participants and speakers at the Manilla combined workshop, May 1999.

training in the use of software for the Revised 1996 IPCC Guidelines. Regarding mitigation, the centre presented the methodological guidelines for mitigation assessment developed within a UNEP/GEF project; the assessment report was broadly distributed in both printed and electronic versions.

As part of the technical assistance to countries, the UNEP Centre has also reviewed the draft inventories prepared by Buthan and Guyana, and the pre-release version of El Salvador's First National Communication.

The workshops on inventories have shown that many countries are worried about how to periodically update inventories. They also lack activity data for certain sectors and consider that improving emission factors is a high priority. As an interim measure, participants agreed that this work could be performed at the regional level through exchange of information and experiences.

A relevant topic of discussion was the uncertainty of national inventories; countries recognised the potentially important role of inventories in the future implementation of the Kyoto mechanisms. Another significant issue raised was the distinction between the purposes of inventories; for national reporting, reasonably aggregated information is sufficient; at the project level, however, highly detailed inventories are needed for mitigation analysis.

Although non-Annex I parties have no obligation to report on mitigation, many countries have already identified options and generic measures, and are willing to improve their analysis for inclusion in the national communication.

The key sectors with potential of mitigation are usually the energy, land use change and forestry sectors. Some models have been applied with varying degrees of success. During the workshops, training on the use of these models and the development of simplified approaches were identified as a need. Where data are unavailable, a priority is collecting regional or country-specific information.

Usually the countries attending the workshops are at very different stages in the preparation of their National Communications. This fact makes it especially difficult to satisfy the wide range of needs, and innovative approaches should be adopted on the way. For example, the workshop on inventories in Barbados started in plenum with formal presentations, but the participants quickly built a consensus that hands-on training with the IPCC inventory software was their real need. It was then decided to move all participants into the computer room. In three days they worked through all the emitting sectors, from energy to waste. After the exercise they felt better prepared to make their inventory.

Regarding the national communications per se, countries considered that capacity building should have two distinct stages: the first to develop technical capacity to prepare initial and subsequent national communications, the second to implement the action plans in the national communications.

Juan F. Zak and Jørgen Fenhann

Safety, Reliability and Human Factors programme

The year 1999 was the first year for this research programme, which originates from the former programmes on industrial safety and human/machine interaction. The aim of the new programme is to develop methods for analysing the safety and reliability of complex technical systems, considering technical, organisational, and human aspects alike. The goal is to develop comprehensive methods by a multi-disciplinary research team. About 20 scientists, psychologists, and information specialists collaborate to solve the many problems that follow with the use of complex technology in a society where safety and reliability have a high priority.

The programme presented itself during a special arrangement in early February 1999. Some 60 representatives from Danish industry, consultants, and authorities showed great interest in a variety of poster presentations and demonstrations.

The programme addresses a wide range of topics. Activities for some topics are described in detail on the following pages, but it is worthwhile to mention briefly some other activities in 1999. In the area of risk analyses and safety reports for industrial plants, implications of safety on land use around an LPG filling plant were addressed. In co-operation with the Danish Ministry of Labour, courses on the implementation of the EU-directive on the prevention of major industrial accidents were arranged for some of the present EU applicant countries. An EU-supported project on uncertainty in risk analysis continues into 2000. Research related to accident consequences was continued with support from the EU 4th framework programme, focussing on the dispersion of HF and prediction of the effects of concentration fluctuations in toxic gas clouds. Activities related to classification and analysis of human error focused on the development of a taxonomy for incident reports within the area of Air Traffic Management, in collaboration with the UK National Air Traffic Services and under contract from Eurocontrol. In connection with this, a PhD project was started on error analysis taxonomy within the same area in order to analyse the mechanisms behind human errors and their recovery. The study will also look at the unknown mechanisms underlying error detection and recovery.

The programme hosts the Centre for Human-Machine Interaction (CHMI), established and supported by the Danish National Research Foundation. Progress in the CHMI is described in a another contribution to this report. We need to mention also the long-term co-operation with the OECD Halden Project and the Danish Maritime Institute (DMI). Within the framework of the OECD Halden Project, a PhD project is being carried out on group situation awareness. Alternatives for displaying traditional information for process control are also investigated. The collaboration with DMI proved once again to be a successful basis for joint project development in the area of improving safety at sea.

A major achievement was the modernisation of the laboratory facilities for empirical studies of human-machine interactions. Following large investments in 1998, the facilities were tested and made operational. Apart from providing high-level support to the programme's main stream of research in human-machine interaction, possibilities for commercial application of the upgraded Human-Machine Interaction Laboratory look promising.

The research programme was also successful in getting approved two large project proposals under the 1st call of the EU 5th framework programme. The main objective of the VINTHEC II proposal is to develop, assess, and evaluate an objective measurement methodology that can be used to appraise flight deck crew co-ordination, in terms of both crews' shared situation awareness and their interaction with automated flight deck systems. The exploitable product of this project would be a methodology for assessing crew co-ordination in operationally relevant scenarios, which can benefit crew training.

The other proposal, COGITO, will become part of the activities in the CHMI. This project seeks to develop techniques for interactive Internet services (e-commerce) that are able to combine the usefulness of modern value-added services together with a high degree of usability, and dedicated measures to build up trust and confidence in inexperienced users.

Nijs Jan Duijm

A turbulent diffusion experiment

The Particle Tracking project is an experimental study of turbulent diffusion carried out by the Systems Analysis Department and the Department of Wind Energy and Atmospheric Physics and sponsored by the Danish Technical Research Council. The purpose is to conduct controlled experiments, which test turbulent diffusion models. Turbulent diffusion has important applications, in particular within risk analysis. There is a growing concern for the evaluation of dispersion models in practical use and for the testing of their theoretical basis. The need for fundamental turbulent diffusion experiments has been recognised for almost a century, but for a long time direct measurements have been overwhelmed by technical difficulties. The difficulty is to measure so-called Lagrangian statistics, which describes the behaviour of the fluid "seen" from points that follow the flow. The Particle Tracking project takes up this challenge.

A water tank was constructed for the experiments. Turbulence is generated by means of two oscillating grids and the water is seeded with neutrally buoyant particles that follow the water flow. Four synchronised video cameras are used to take stereoscopic images, which are digitised and stored on-line by two computers. Software has been developed that reconstructs the three-dimensional positions and identifies particle trajectories in a time sequence. The method allows co-ordinates to be determined with an accuracy of 60 µm within a cube about 15 cm wide.

Figure 1 shows reconstructed particle trajectories from a 1 second subsequence (the whole sequence is much longer). The disordered, almost spaghetti-like appearance is typical, but the trajectories are not completely independent. When two particles come within a short distance of each other they have a strong tendency to stay together afterwards. This is because only a small "eddy" can catch one of the particles without catching the other one also, and in turbulence small eddies are generally rarer than larger ones. Therefore, the particles break away faster as they become further apart where larger eddies can become effective. The term "anomalous diffusion" is sometimes used to underline the accelerating nature of the process. Investigating the anomalous diffusion was the primary objective.

It is generally accepted that in the anomalous regime the average of the square separation, σ^2, follows the simple law $\sigma^2 = C\varepsilon t^3$. Here ε is the rate of energy dissipation per unit mass, t is time counted from the moment the two particles were close together. C is the Richardson-Obukhov constant, which is a dimensionless number. Since the formulation of the law, more than fifty years ago, there has been a characteristic lack of consensus about the value of the constant C. The various theoretical predictions of C range from 0.01 to 10, thus differing by more than three orders of magnitude. Experimental values of C are scarce and they too scatter over a wide range, roughly between 0.01 and 1. Our measurements narrow this range to C = 0.4-0.6. This interval rules out the majority of the theoretical predictions of C, many of which are a factor ten too large.

Results include details about the so-called distance-neighbour function q(r,t), a measure of the probability of separation r at time t. To our knowledge these are the first measurement of q in three-dimensional turbulence. In Figure 2 experimental results have been plotted along with curves based on three different theories. The

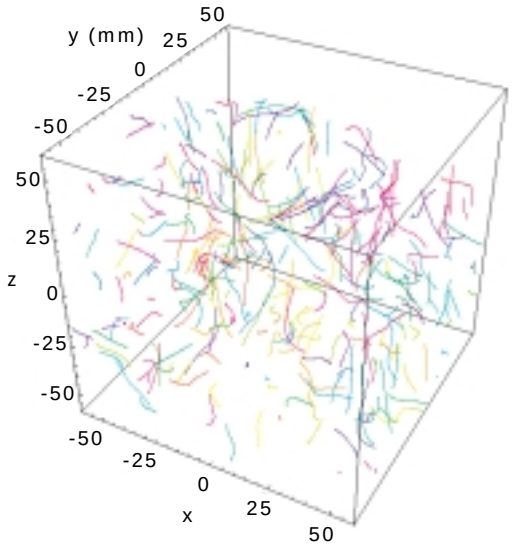


Figure 1. Tracks measured simultaneously during one second. The system can handle 1000 particles at a time.

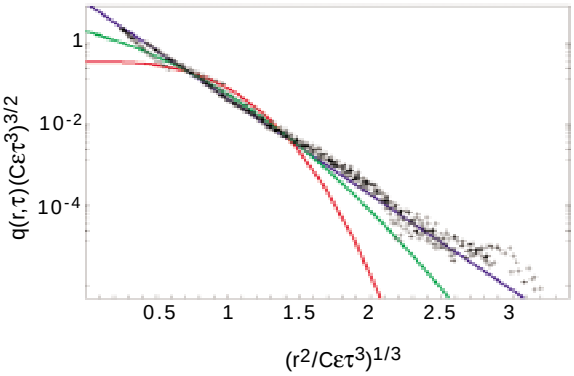


Figure 2. Experimental results for the distance-neighbour function (marks) and theoretical predictions: red (Richardson, 1926), blue (Batchelor, 1952), green (Kraichnan, 1966).

experimental data cluster around a single curve, a straight line in this plot, and apparently only one of the theories is consistent with data. This theory is, in fact, the oldest of them all. It is due to Richardson, who invented the concept of relative turbulent diffusion back in 1926 and offered the first model for q. The other models, due separately to Batchelor and Kraichnan, are perhaps the two most famous attempts to improve and substantiate Richardson's ideas. Like Richardson's model, Batchelor's model is relatively simple, whereas Kraichnan's model is part of a grand scheme, called the Lagrangian-History Direct-Interaction Approximation, designed as a general approach to turbulence. Kraichnan's theory has been applied successfully to a number of other turbulence problems, but apparently it does not reproduce the shape of the distance-neighbour function, and the predicted value of C is ten times too big. These results show that a unified theory of turbulence still lies far ahead, but hopefully this work will contribute to a fruitful interplay between theory and experiment in this area.

Publication in 1999: 53
Søren Ott

Risk analysis of pork production focusing on human and organisational factors

As a general principle, the European Union stated that food production should not involve a risk of food-borne diseases. However, food-borne diseases still represent a problem, and the presence of human salmonellosis and salmonella-contaminated food products is observed with increasing frequency in many countries. In parallel with the global trend, human salmonellosis is also an increasing area of concern in Denmark.

In the last decade great emphasis has been put on individual and organisational factors in safety studies of the process industry. The concept of risk analysis in relation to food production is still in its infancy. Several risk assessments have been carried out with respect to microbiological hazards and food-borne diseases, and one commonly used approach is the development of a quantitative risk model in combination with Monte Carlo simulation. Today, the analysis of food safety is also facing the difficulty that the efforts which have focused on scientific and technical aims are by themselves insufficient to reduce food-related risks to an acceptable level. The investigation of food safety problems indicates that organisational deficiencies are also contributory factors.

In co-operation with the Danish Bacon and Meat Council (Danske Slagterier), a feasibility-study was carried out on the impact of individual and organisational factors on salmonella transmission and contamination in the Danish pork production chain. The idea was to investigate the extent to which the experiences gained from risk analysis and risk management of the process industries can be adapted and applied in the pork industry and food safety in general. In a long-term perspective the goal was to obtain a better understanding of the factors influencing food safety in order to reduce the number of people affected by salmonella-contaminated pork. The study focused on the primary production of pigs and the transportation and slaughter processes.

Pork production and salmonella control in Denmark

Denmark produces approximately 20 million slaughter pigs per year. In 1995, a salmonella control programme with its goal to eliminate pork as an important source of human salmonellosis was implemented. The programme comprises surveillance and interventions at the level of feed mills, breeding, and multiplying herds, slaughter

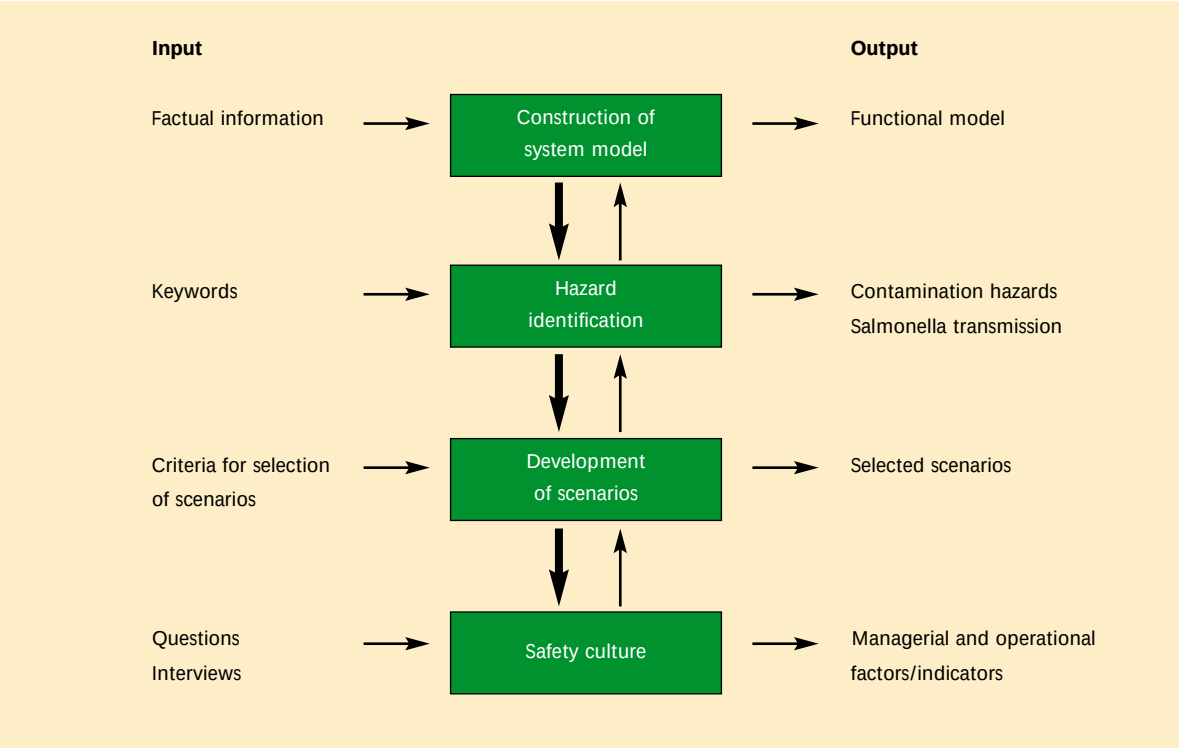


Figure 1. Overall structure of the methodology

herds, slaughterhouses, as well as the final product, fresh pork. At present, the level of occurrence of salmonella in fresh pork produced in Denmark is approximately 1%, and approximately 10-15% of all salmonella infections registered in Denmark are related to contaminated pork or pork products.

Methodology

The overall outline and an overview of the methodology can be found in Figure 1 showing the inputs and outputs of the different steps. Based on the system models and hazard analysis it is possible to identify hazardous conditions or processes, but the event sequences leading to the unwanted events are not necessarily obvious. Individual and organisational factors were described in scenarios inspired by an organisational scenario model comprising an event chain, existing controls, possible unwanted conditions/events, and possible error/violation promotion conditions. In parallel safety culture aspects at the primary production and slaughterhouse levels were provisionally assessed using the principles of qualitative research interviews.

Methodological results

The hazard analysis based on a functional model proved to be applicable in the area of food safety with some adjustments such as the development of new key words. Despite the fact that the method is typically applied to one individual plant, it was possible to accommodate the range of practices used when considering, for example, pig farms in Denmark. When various options were possible for a given process, they were all listed as equivalent methods. Although, salmonella-related risks were the focus of the study, it appears that the functional model in principle can be used to analyse other food-borne diseases in the pork production chain.

Pork production is a large industry divided into separate units and functions. Most of the actors have well-defined tasks, but are concerned only with a limited section of the whole system. This circumstance implies that it is difficult for a single person or group of actors to have an overview of the whole production line. From this it follows that interfaces between the different areas of responsibility become particularly important to ensure that all aspects are addressed appropriately. The success of the pork production industry depends to a large extent on consumer confidence and export markets, and the inappropriate conduct of some actors will damage the entire industry. Therefore, it is of interest to have a common understanding of food safety problems and the motivation for solving them. An essential motivating factor to implement appropriate salmonella safety measures in the primary production seems to be economic sanctions.

Publication in 1999: 104

Birgitte Rasmussen and Kristian Borch

Dangerous goods and the Øresund Link

A 7.8-km bridge and 3.5-km tunnel have been built to link Malmö with Copenhagen. The connection is to be opened for trains and motor traffic during the summer 2000. Representatives from the Danish Beredskabsstyrelsen and the Swedish Räddningsverket and from local fire defence and police authorities in both countries formed a group working on rules for dangerous goods. Risø was consulted by the group and presented with a choice of six solutions: five specific restrictions, detailed by the group, plus the "zero solution", with ADR- and RID-rules being the only restrictions. The idea was to point out the best solutions from the viewpoint of individual travellers' risks.

Restrictions on transported goods must be investigated, because risk contributions from transported goods in the view of possible accidents may be intolerable to other users of the link, and some classes of goods may present risk to the bridge and tunnel structures as well. Restrictions placed on one route may lead to more goods transports on alternative routes, which in their turn may influence the risk picture in the region.

Other analyses had already been made, including risk analyses and a prognosis on dangerous goods transport. Therefore, we found that producing further risk data for the decision process should not be our prime concern. Instead, we aimed at constructing a dedicated decision model, which could be used by the decision-makers themselves. In the absence of absolute norms for passenger risk, one must weigh risk with economy, with political views, and with public risk perception to make a workable decision. The model is inspired from the results of an EU-supported project LUPACS under the Environment and Climate programme. With the model one can allow several parameters to influence the decision in addition to the risk data.

Besides constructing the decision model, Risø compared goods transport on the link with that on the ferry route between Helsingør and Helsingborg. These efforts had as their primary goal to enable one to rank the given six restriction types with respect to risk parameters. The study brought together a picture of the risk changes when a transport is switched between the Link tunnel and the classical ferry route with additional road and rail kilometres for the transports concerned.

The choice of a set of restrictions is by nature a multi-objective decision; the decision involves several actors and the outcome affects many interests of the public. Large uncertainties exist in input parameters such as traffic densities, goods transported, consequence calculations, and public reactions. One objective was therefore to set up a method for choosing restrictions, which was tolerant to small changes in input values. Another objective was that the method should be workable for the main actors to the extent that they could adjust results themselves with alternative input conditions and with future realistic values.

Evaluation of a restriction

The restrictions dealt with are means for controlling danger potentials, operating through restricted amounts of certain classes of transported goods. As demonstrated so clearly by the Mont Blanc tunnel fire in March 1999, dangerous transports need not involve substances, which are classified as dangerous. The Mont Blanc Tunnel fire

THE PHOTO ARCHIVES/ VISION, SØREN MADSEN

Figure 1. Interior of the immersed road tunnel of the Øresund Link.

was fuelled mainly by flour and margarine. The Øresund Link could not be said to be comparable to the French-Italian mountain tunnel, but the matter of classifying goods after their danger potential is indeed a universal problem. Quite ordinary goods and many of the items we want to carry in our cars or in our luggage when travelling may contribute further calories in addition to those brought by vehicle materials and fuel.

An expedient way to decrease the probability of such "normal" tunnel fires will be simply to set tight limits on the size (weight) of transport units: cars, trucks, rail cars, and to separate goods from the travellers on the link.

Multi-criteria decision scheme

Following the multi-criteria decision approach, different weights can be assigned to each criterion. Using this tool repeatedly one gradually acquires an improved insight into the problem and may adjust weights and uncertainties to gain an optimal result.

Usually the balancing of risks, benefits, and costs is hidden within standards, practices, and ALARA-type principles (As Low As Reasonably Achievable). Using a multi-criteria decision scheme with specified weights, one establishes a new class of both operational and informative risk decisions. Even results expressed in rankings and weights described as high, middle or low, may convey more useful information about the decision problem than does any set of risk calculations.

Our investigation led us to suggest rankings of the six solutions after risk parameters, after restriction parameters, and after conditions for emergency operations. One assumption behind the risk ranking is that large explosions or fires can be better tolerated on goods ferries than on the fixed connection.

Publication in 1999: 58

Carsten Grønberg, Birgitte Rasmussen and Frank Markert

Safe navigation in coastal waters – evaluation of a new type of display

Risø has together with the Danish Maritime Institute carried out an evaluation of a new conning display developed by Kelvin-Hughes. The evaluation was part of the EU-supported project SAFECO II (Safety of Shipping in Coastal Waters II). A conning display shows key information concerning one's own ship, such as position, heading, speed, engine data etc. and is usually located in the centre position on the bridge.

Apart from the usual information found on these types of displays, the Kelvin-Hughes system also displays an electronic map. It has as a new feature a collision avoidance advisory system. The goal of this system is to decrease the number of collisions that might have been prevented, if in each case, advice had been available from

Figure 1. The Kelvin Hughes conning display in navigation mode

an expert onboard. The collision avoidance advisory system thus gives advice to the officer on watch based on the rules of the sea in the specific water and, using information from the radar, about other ships in the fairway. The collision avoidance advisory system is developed because a number of collisions take place when the navigators neither follow the rules or know how to use them (these factors are present in nearly 50% of all collisions). The interesting task in this project was to evaluate the potential impact of this collision avoidance advisory system on the bridge.

In the situation where another ship is observed, the following questions in general are asked:

- Has the other ship seen me?
- Has she a stable course and speed?
- Can I safely avoid a collision?
- What is the risk of grounding?
- Does she follow the nautical rules?
- Given more ships around, what can I do?

Provided that the answers to the questions 1 and 5 are both positive, the collision avoidance advisory system assists with answering questions 2, 3, 4 and 6. If the answer to question 1 is uncertain, then the answer to question 5 is also uncertain, and in this case the advisory system is not able to provide trustworthy support.

The conning display was set-up at Risø and connected to the Danish Maritime Institute Simflex simulator in order to evaluate the system. Mariners were invited to use the system and their comments were collected. The result of the evaluation showed that the new conning display included a number of useful features. The combination of radar data with sea chart information gives the mariners the necessary information to be able to judge potential manoeuvres in coastal waters of other ships beforehand. However, a number of features were not presented in an optimal way, i.e. comparable sets of data, like the speed/course over ground versus speed/course through water, should be positioned in close proximity. Furthermore, information usually found on this type of display was not included due to the limited space available.

The collision avoidance advisory system will offer advice in situations which are present in approximately 50% of all collisions, namely uncertainty about one's own ship position or misjudgement of the movements or intentions of other ships. Results indicate that the performance of the advisory system is as good as that of an experienced officer. However, a number of cases were identified where a single failure either by the bridge officer or in the radar could lead to a collision. This is caused by a lack of relevant information being supplied to the advisory system.

Steen Weber and Jette L. Paulsen

Task-oriented display strategy

The design of display systems for process plants requires a study of the system in question, its behaviour in normal operation mode, the failures that may occur, and their consequences. Furthermore, it is also necessary to know how the plant degrades during time. Methods, which can help the designer in making displays with the necessary information for the users, are studied in a collaborative research project with the OECD Halden Reactor Project in Norway.

The content of the displays must reflect the goals of the plant and also the tasks of the operators, which for modern process plants mainly are supervision of the automatic process, but also the ability to intervene in the process if the process performance deviates from normal conditions. To be able to intervene in the process in the case of an abnormal situation requires a good situational awareness of the plant performance, which requires a good content and design of the operator interface.

The design strategy in this project starts with a listing

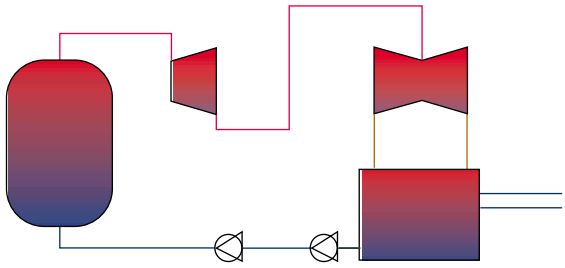


Figure 1. Thermal power-plant diagram

of the goals of the plant. For complex process plants there are several goals. Optimal profit could be a goal, but optimal profit can be influenced by factors other than plant performance, so in this study the overall goal for the plant is to operate at an optimal production level. Optimal production requires optimal operation, which requires high availability of the plant, optimal maintenance strategies, and high safety conditions. These goals must be easy to observe in the information to the operators.

For some plants safety is very important and for others less important. In chemical production with risks for run-away reactions or risk for release of toxic material, safe operation is especially important. A classification of the goals of the information system will be appropriate. Examples of goals are the following

- Production
- Operation
- Safety
- Maintenance
- Diagnoses of failures

During the design of the plant, components are selected to meet the required process.

Optimal operation and efficiency of the plant means that the plant is run as the plant designer intended. All components have built-in working characteristics, where the components function optimally. The idea is to use these characteristics in the design of displays, as a reference for optimal operation and optimal maintenance. For optimal maintenance decisions the characteristics are used as references for when to maintain the components; for optimal production the characteristics are used as references for optimal production.

A system, which has been studied using component characteristics, is the condenser system of a power plant. This problem has been studied together with nuclear power plants in Sweden in a Nordic Nuclear Research (NKS) project. For thermal power plants the condenser is the most important component influencing efficiency of the plant and thereby optimal production. The pressure in the condenser determines nearly absolutely the efficiency of the whole plant. Therefore it is important to be able to inform the operator about the function and condition of the condenser, so that action may be taken in time if the function or condition is disturbed.

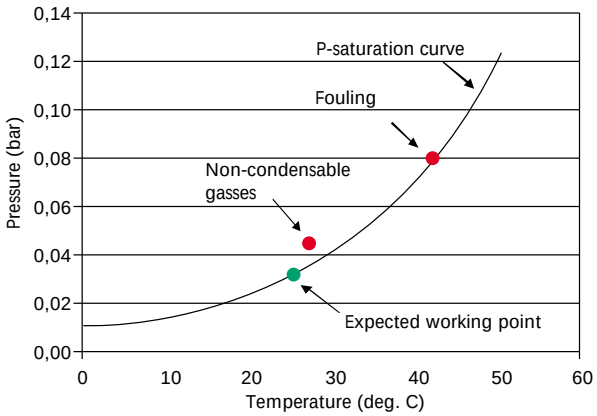


Figure 2. Proposed display for a thermal power-plant condenser

To be able to extract the information necessary for the operator to be able to observe deviations from optimal operation, a general task-oriented strategy has been developed for the design of operator displays. The strategy applied to the condenser system results in the following series of questions and answers:

What is the goal?	→	Keep pressure low
What are the problems?	→	Temperature increase in the condenser Existence of non-condensable gases
How do they occur?	→	Cooling problems Ejector problems Incoming air leakages
How is it observed?	→	Increase of condenser pressure
How should it be presented?	→	As a deviation from the expected working point on the condenser characteristic.

The first four questions require a systems analysis of the systems, its intentions and functions, together with a hazard analysis to elicit the problems and their causes. The last question requires first of all a presentation of the parameters necessary to observe the changes. In this case it is the pressure in the condenser. The operators are interested in the cause of the pressure change, so a diagnosis on the problem can be made to enable action to be taken. In the case of the condenser the curve for saturated steam is an invariant of the system on which the condenser has its working point. The ability of the coolant medium to cool the condenser changes during the year because it is dependent on the cooling water temperature, which therefore determines the exact working point on the saturation line.

Figure 2 shows a proposal for a condenser display. The following two unwanted situations can be observed: (1) In case of problems with the ejector system or a leak with incoming air in the condenser, which overload the ejector system, non-condensable gases will be present in the condenser. The pressure in the condenser will increase with the partial pressures of these gases and the working point will lie above the saturation curve. (2) Fouling on the heat transmission surfaces is a normal degradation of the system. If fouling occurs, the working point will still be on the saturation curve, but at a higher pressure and temperature. The display can support the decisions about when to clean the pipes. Problems with the capacity of flow of the coolant medium will show the same deviation as fouling and the working point will still be at the saturation curve.

Jette L. Paulsen

MEMbrain: A system supporting Major Emergency Management

A decision support system, MEMbrain, supporting emergency management, was started as a European project in 1993. The project was initiated by Cap Gemini Innovation in France and – based on the experience at Risø from the previous EU projects ISEM and MUSTER – Risø was invited to participate in the MEMbrain project. The name was chosen partly from the idea of a brain supporting Major Emergency Management, MEM, and partly with associations to a membrane filtering the information available in a crisis situation to the amount of information needed for efficient handling of a critical situation. The project was planned as a modular system with various participants responsible for specific modules, and Risø was responsible for two very vital modules, a "communication module" and a "training module". Initially, the project had participants from France, Norway, Finland, and Denmark as initial developers, and from Greece, Italy, and Portugal as end users with specific applications of the system.

The project was funded as a EUREKA project, which means that all participants had to find their own funding nationally. Risø was funded by The Danish Agency for Trade and Industry (Erhvervsfremme Styrelsen) for the complete duration of five years and has accomplished – in co-operation with IFAD (Institut for Anvendt Datateknik) – the building of two modules: MMS (Message Management System) for communication within an emergency managing organisation, and MUSTER (Multi User System for Training of Emergency Response) for performing interactive training of co-ordinated action in critical situations. The name MUSTER was taken over from the previous MUSTER EU project as a synonym for a multi-user system, and simultaneously having the meaning of gathering forces to cope with specific tasks.

The marketing of MEMbrain was taken care of by Quasar Consultants A/S in Norway, and notable interest for the system has been shown by several countries, especially China, India, and Ukraine. However, a complete MEMbrain system has until now been delivered only to the Nuclear Radiation Protection Agency in Norway.

The MMS system is an emergency management dedicated e-mail system ensuring reliable communication supported by such features as reminders, holding track of related communications, and securing that orders are received, understood and fulfilled.

In its first phase the MUSTER system has been developed as a network-based interactive pre-hospital training system for medical doctors. For this module Risø and IFAD has co-operated with the Copenhagen Hospital Emergency Planning, the Danish Defence Research Establishment and The Army Combat School. The training module may be used for training medical doctors in the initial stages of first medical care on site, and stabilising casualties before being transported to a selected hospital. Furthermore, and even more important, the module may be also used to train medical doctors for co-ordinating their actions with the other parties at the scene, the fire brigade, the police, etc.

The module has been presented at several occasions to medical doctors, police, and fire fighters. It has been received with great interest, and test systems have been requested from Danish counties as well as from interested parties in Spain, England, Austria and USA. The first version has been bought by the Copenhagen Hospital Emergency Planning to be used for education and training at the hospitals in Copenhagen.

The future plans cover the development of similar systems for the police, the fire brigade and other parties that may be included in the complete emergency management organisation at major emergencies. Thus, a training system for the complete emergency organisation will become available by integrating all these modules.

Publication in 1999: 114
Verner Andersen

Centre for Human-Machine Interaction

The Centre for Human-Machine Interaction (CHMI) was established by the Danish National Research Foundation 1 March 1998. The centre is a partnership between Risø (the host institution), Aarhus University, Technical University of Denmark (DTU), Danish Maritime Institute and Danfoss A/S. It is organised as a research network between scientists and PhD students with a main interest in cross-disciplinary aspects of human-machine interaction and their implications for the design of systems, which support rapidly changing, co-operative work. In 1999 the department's contribution to the centre activities was significantly strengthened by the employment of two new staff members recruited from the fields of computer and information science. Risø's engagement with CHMI now includes six people of whom four are fully financed by funding granted the centre by the National Research

Foundation. In addition to contributing to the implementation of the centre's research plan, the department undertakes the task of managing and administrating the centre in collaboration with its centre associates at Aarhus University.

The aim of the joint activities in the centre is to acquire an improved theoretical understanding of human behaviour in complex, technologically advanced work settings, and, based on these insights, to develop novel principles for designing work-centred human-machine systems. Taking part in basic research of this nature brings about new inspiration and opportunities in the department for continuing a long-lasting preoccupation at Risø with Cognitive Systems Engineering. Theoretical knowledge and empirical findings in this and other areas of the centre's research are of interest to the further development of the Safety, Reliability and Human Factors programme.

Risø's contribution to the CHMI research plan is focused on knowledge exploration and information seeking performed by collaborating actors in engineering design, software development and other work domains characterised by an intensive use of information and knowledge retrieved from many different sources and media. An important objective is to investigate how such activities can be supported.

Early in 1999 a longitudinal field study of a large software development project in a major Danish software house was started. The data collected so far cover the formative eight-month period from the initiation of the project, through the requirements specification, to the completion of the business modelling. The analysis of this empirical material, which consists of tape-recorded project meetings, interviews and copies of project documents, has focused on the fundamental importance of trust in engineers' assessment and choice of information sources. It was observed that the engineers give much consideration to sharing information that helps them in assessing the trustworthiness of their sources. To be able to make these assessments with confidence they prefer familiar sources, which tend to be internal.

In 1999 Risø has furthermore entered into a partnership with University of Washington (Seattle), Microsoft Research and The Boeing Company in a project on Collaborative Information Retrieval (CIR). This project has background in the fact that it is becoming more and more critical for individuals and organisations to manage and retrieve the flood of information they receive. Most information retrieval and management tools have been developed for use by individuals. However, today people most often work together in teams and share information sources as well as retrieval strategies and search results. The goal of the CIR project, which is supported by the US National Science Foundation, is to obtain a better understanding of the social and collaborative aspects of information retrieval in a variety of modern work settings. Risø's and hence the centre's role in the project is to further develop Cognitive Systems Engineering with a view to providing guidance in empirical studies of collaborative work and organisational behaviour and the design of so-called ecological information systems in the area of CIR.

The research carried out elsewhere in the centre covers other empirical domains and is based on different theoretical approaches. A group composed of staff from the Department of Computer Science at Aarhus University and User-Centred Design at Danfoss have Common Information Spaces as its area of interest. A major achievement in 1999 was a field study of the work processes at three waste-water plants followed by information-system design studies and the development and evaluation of a prototype system. Centre staff from the Department of Information and Media Science at Aarhus University, the Department of Automation at DTU and the Danish Maritime Institute have chosen maritime manoeuvring and navigation as their target of joint empirical work. In 1999 a large corpus of transcribed video recordings of the human activities on a modern ship bridge was produced from a sea voyage with a big container vessel undertaken by two members of the group. The aim of these studies is to make scientifically motivated suggestions for designing adaptable interfaces for computerised maritime instruments and to develop a dynamic framework for the analysis of communication, co-operation, and action in the area of process control.

An important part of the research within CHMI consists in shared efforts to elucidate and compare the theories and methods used by the various centre groups as a basis for their empirical studies and design-oriented activities. A two-day symposium on the theories and methods of Computer Semiotics, Cognitive Systems Engineering, and Activity Theory was held in October 1999.

Publications in 1999: 8, 27, 65, 99

Annelise Mark Pejtersen and Leif Løvborg

Three studies of professional information-seeking practices

The roles of documents in professional work

Documents are used extensively by professionals in the execution of their own work and in the sharing of information with others. Professionals use and manage their documents in ways that are woven into their work activities and leave most of the context unsaid because the documents are understood as belonging to a certain ongoing activity. Through a series of case studies within the Centre for Human-Machine Interaction, we have identified six roles documents play in the work of professionals. These are that documents serve as: personal work files; reminders of things to do; a sharing of information with some, yet a withholding from others; conveyors of meaning; a means of generating new meaning; and mediators of contacts among people. In specific case studies of engineers, it has been established that most of their information comes from colleagues and internal reports and not, as is typical in scientific domains, from external publications. The studies have investigated how engineers' information-seeking practices intertwine searching for informing documents with searching for informed people. An analysis of case studies in two product-development organisations reveals that engineers search for documents to find people, search for people to get documents and interact socially to get information without engaging in explicit searches.

In a way, the authors of archived documents have been indexed with their documents, and it is thus possible to use the contents of the documents, and the keywords assigned to them, as descriptors of the knowledge and skills of their authors. In this way, document archives can be, and in fact are, used to search for people. Searching for people is, however, seldom acknowledged as an essential function in the design of document archives, which give much consideration to preserving the past and comparatively less to maintaining links with the present. Given the immense importance of interpersonal communication in engineering work it seems well worth the effort to consider extending document archives with facilities for searching for people. A simple move in this direction would be to provide current contact information for document authors and other people mentioned in the documents. Another approach to supporting the use of people as information sources is to design services dedicated to searching for people. This requires detailed knowledge about what information professionals rely on in finding and selecting the people they consider capable of helping them. This issue has to be explored further in order to bring about a reasonably complete scheme for classifying the involved pieces of information. Current case studies are also investigating to what extent the collection of such information can be turned into an automated process independent of people's diligence in performing recurrent manual procedures.

Retrieval of video documents

With the rapidly decreasing cost of digital storage and computer power, it is now becoming common practice for video production studios to edit and produce video programmes purely digitally. This has led to an increasing demand for standardisation of video indexing to support the searching of large archives of digital video, starting with the development of the emerging MPEG-7 video indexing and retrieval standard. In a collaboration between the Centre for Human-Machine Interaction, Teltec Ireland and Dublin City University, a query application for the DICEMAN EU-funded ACTS project on distributed internet content exchange using MPEG7 and agent negotiation was developed using user-centred design techniques. The query application was developed to support different search strategies of professional users accessing large video archives that have been indexed with a complex indexing language. The strategies, which were initially established at Risø in the domain of fiction retrieval, were:

- bibliographical searching for known features of relevant material, such as title or writer;
- analytical searching (structured refined querying following a problem-solving approach);
- similarity searching based on known relevant items;
- empirical suggestions based on known user characteristics;
- and free-form browsing.

Within the DICEMAN project, these search techniques highlighted searching approaches that had not previously been considered within the video indexing project. For example, the database was redesigned so that any video clip could be queried to give a description of the clip that is suitable for presentation to the user as a new query, thus supporting a smooth transition from analytical searching, through similarity searching, and back again to analytical searching.

Figure 1 shows the results of a user having found a list of matching video clips, with Le Medecin Volant de Moliere being the best match. The user then carries out a similarity search to create a new editable query where he/she specifies whether it is the character, the colour of the scene or the camera motion that is more important. Suggestions were also made to use the DICEMAN Agent

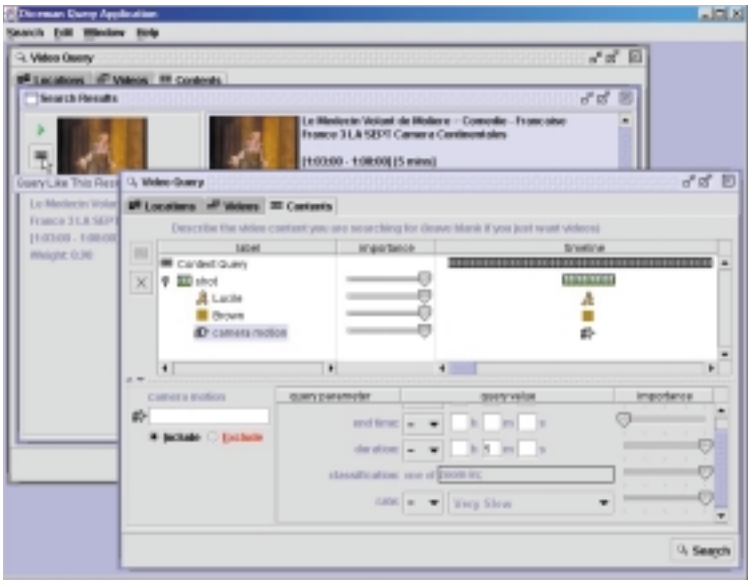


Figure 1: A sample video retrieval search building from results of a previous search

architecture to support empirical suggestions and freeform browsing based on a negotiation between the user and provider agents. The participative design and developing of the interface included initial user tests of building complex queries using the query interface. These tests showed encouraging, if preliminary, results that users are able to both remember camera level activities and convert high level queries into low-level characteristics (which, for cost reasons, are likely to be the main indexing methods for MPEG-7). The research theme of understanding end-user interaction with agent-based systems is now being followed up within a new EU project, COGITO, investigating the use of agents in e-commerce.

Information seeking in public service organisations

Public service organisations are characterised by a high degree of task uncertainty. Making the right decision is constrained by changing policies and differences in professional perspectives and values. Task uncertainty poses significant challenges for developing information environments to support individual and group decisions in the domains. The design of work-based classification systems is a project which explores Risø's Cognitive Systems Engineering approach for analysing a work domain with the purpose of designing an information system to support cognitive user tasks in a work domain. The domain analysis captures the professional perspectives and values, the information resources and the goals and intentions within an organisation. From this mapping, classificatory structures are developed to support decisions through a map of domain characteristics and values. Recent studies of work-based classifications have shown that classifications function as invariant semantic infrastructures that facilitate understanding by professionals of both corporate goals and intentions and the variety of domain knowledge of the actors. Current field studies on work-based classifications within the Centre for Human-Machine Interaction explores the Cognitive Systems Engineering approach to work domain analysis in a Danish public organisation.

Publication in 1999: 77

Morten Hertzum, Mark Dunlop and Hanne Albrechtsen

The Human-Machine Interaction Laboratory

During the last decade we have witnessed a greater focus on the human element in systems design, which in many cases have led to improved user interfaces. Too often, however, system complexity, confusing interfaces and inadequate attention to diverse users lead to human errors, confusion and frustration. A detailed understanding of the way users mentally process the information presented to them is essential, not only for the purpose of designing efficient interfaces, but for evaluating these systems as well.

The Human-Machine Interaction Laboratory aims at facilitating our scientific understanding of usability aspects of the interaction of humans with computers and other systems. This understanding is advanced through both field studies in users' workplaces and laboratory experiments with trial subjects. The facility has been established to strengthen the programme's experimental research basis in the HMI areas of:

- System use and analysis of usability evaluation methods and simulations;
- Evaluation and analysis of human-machine interfaces;
- Field studies of individual and team-based work activities.

To support the evaluation activities better, it was decided

to upgrade the experimental facilities to include remote eye-tracking devices, a synchronous digital head- and eye-tracker, a full-scale portable usability lab, and advanced software-based analysis and visualisation tools.

The descriptions below give examples of the methods used in examining human-machine interfaces. The choice of method depends on the application domain.

- Field studies are very often the choice due to the nature of the domains we are facing in our work (product development, control rooms, cockpits, ship bridges, large-scale simulators, etc.) Also, with respect to software development and the development of mechatronic systems, it is very often a requirement to carry out experiments on location, due for example to confidentiality requirements and to gain an accurate impression of work practices.

- Cognitive role playing is a review technique where scenarios are set up for tasks based on requirements specifications or an early prototype.

- The "think aloud" protocol is a rather simple but very powerful method for evaluating user interfaces. A user is given a task and asked to think aloud while accomplishing it, possibly with encouragement from the observer.

- Heuristic evaluation is based on in-depth expert analysis of the interface to establish whether the interface follows a set of established rules.

A number of comparative studies of evaluation methods give some guidelines in making a right choice for assessing usability. On the other hand, the validity of these methods has recently been questioned by researchers who argue that many studies suffer due to scientifically poor experimental design. "Triangulation", i.e., an HCI (Human-Computer Interaction) method approaching research subjects from various points of view, has been proposed to overcome the shortcomings of single usability methods. Along this line we combine an analysis of visual behaviour with that of verbal and system data to obtain a complete basis for deciding on precisely what user interface components the user focuses on.

Tracking of eye movements assists in analysing visual information gathering and visual attention with a view to the identification of user focus and decision strategies. In making use of this technique, we get a detailed understanding of the way users process information presented in the user interface. With our head-mounted equipment for combined tracking of head and eye movements, we perform digital real-time registrations of visual focus. Laser technology makes it possible to register the environment in three dimensions and automatically map it into the computer. From this information the computer calculates where the user is and combines these calculations with the registrations of the person's point of gaze.

Figure 1. Head-mounted equipment for combined tracking of head and eye movements

Figure 2. Remote eye tracking device

Our remote eye tracking devices operate without recording gear affixed to the user. This feature enables us to carry out more detailed usability evaluations and study people collaborating through the interface. The remote eye tracker is placed in front of the subject below the line of gaze. Then it tracks head and eye movements by means of a computer-controlled video camera with focus and zoom, mirror technology and infrared light.

Hans H.K. Andersen and Steen Weber

Technology Scenarios programme

The aim of this programme is to make analyses of commercial, societal and scientific possibilities and their consequences in relation to the selection, development, and commercial application of new technologies. In 1999 the activities of the programme focused on two research themes.

The first of these is the development of methodologies for technology foresight studies and other methodologies for setting priorities for technology-oriented research. Theoretical and methodological aspects of scenario building have been studied in order to identify areas for further research and the application in technology foresight processes in Denmark. Also international experiences on other technology foresight methodologies have been studied aiming at the development of technology foresight within a Danish context. Under this research theme, an internet-based scenario building tool was also developed in task-shared co-operation with the Centre for Business Studies at the Danish Technology Institute and the two firms, TeleDanmark Udvikling A/S and NKT Research Center A/S. Furthermore, a study on the interaction between scenario methodologies and technology foresight methodologies has been carried out as well as studies on the boundaries between technology scenarios and science fiction. Finally, the programme has joined a new network (with the acronym EXCETP) organised by the International Energy Agency on experience curve methodologies as a tool for assessing energy technology policies. Other partners in the network are Lund University in Sweden, Institut Für Solare Energieversorgungstechnik in Germany and National Renewable Energy Laboratory in USA.

The second research theme is developing operational theories and methodologies to embody foresight elements in methodologies for life-cycle assessments (LCA). Under this theme a project has been carried through on a transgenetic high-value ryegrass. The study focused on definitions of system boundaries and preparation of life cycle inventories aiming at preparing a framework for comparative analysis of the application of genetically modified ryegrass and conventional ryegrass. The study has been carried out in co-operation with Risø's Plant Biology and Biogeochemistry Department and the research division of the plant breeder DLF Trifolium A/S.

The established international Scientific Advisory Panel was re-appointed in 1999 for a two-year period. The panel includes 11 Danish and international members with an international industrial or scientific background. The panel held its meeting in October 1999, and the discussions on the meeting have been most valuable for the further scientific development of the programme.

During 1998 and 1999 a large number of project proposals have been formulated in co-operation with Danish and international partners. The second half of 1999 marked a significant breakthrough for the programme when four of these project proposals with external funding were approved.

First, through the so-called SUE-programme, the Danish Research Agency has supported the project "R&D Management Processes under Rapid Change (REMAP)". REMAP integrates researchers from Copenhagen Business School, Risø National Laboratory, the Danish Institute for Studies in Research and Research Policy, Danisco Biotechnology A/S, Haldor Topsøe A/S, TeleDanmark Udvikling A/S, NKT Research Center A/S, Reson A/S, and the Institute of Drug Analysis A/S. The main effort of TES in the project concerns technology foresight methodologies.

Second, a preparatory and planning part of a project aiming at developing technology foresight methodologies as strategic tools for small and medium-size enterprises was inaugurated in 1999. The preparatory project is financed by – and carried out in co-operation with – the Confederation of Danish Industries (Dansk Industri) and the Central Organisation of Industrial Employees in Denmark (CO-Industri).

The third new project is entitled "Decentralised generation technologies – potentials, success factors, and impacts in the liberalised EU energy market" with the acronym DECENT. Risø is task leader on a project module, where Delphi methodologies are applied to identify expected or likely future developments in decentralised generation technologies. The project is financed by the EU 5th framework programme and carried out in collaboration with the Institute for Futures studies and Technology Assessment (IZT) in Germany, ECN in Holland, COGEN Europe, WRE AG in Germany, and Jenbacher AG in Austria.

Fourth, through the so-called BIOTEK programme, the Danish Research Agency has co-funded a three-year project titled "Living with Biotechnology – Genetic Modifications of Crops and Laboratory Animals" with the Royal Veterinary and Agricultural University as project leader and a number of other research institutions – including Risø – as partners.

Furthermore, as a part of Risø's strategy process during 2000, TES will carry out a technology foresight project with the aim of supporting the prioritising of Risø's activities for a four-year period beginning 2002. Risø's Management finances this project.

Per Dannemand Andersen

Methodologies for Technology Foresight and Scenario Building

One of the most important tasks for the Technology Scenarios programme in 1999 was to identify methodologies for technology foresight suitable in a Danish context. This task has been approached through studies of international experiences, through discussions with Danish stakeholders, and through pilot projects. The paragraphs below report on the major findings in this area.

First, definitions, aims, and what Technology Foresight is all about have gradually changed over the recent decades. Therefore, it is important to emphasise that the process of technology foresight and the dialog between the participants is a heuristic process, which becomes more important in the form of the final report or what else might be the final product of such a process. By scientists within academia (universities, national laboratories, research centres, etc.) technology foresight is often perceived as an attempt to limit their scientific autonomy. But this is not really the case, for foresight processes aim to enable proactive participation of scientists in the policy-making process. Technology Foresight is an attempt to analyse a technical issue in a perspective broader than normally allowed by research rooted in a single scientific discipline.

Second, rationales of foreign technology foresight programmes usually are defined in relation to national or governmental policies on science and technology (macro-level programmes). For Korea and other newly industrialised countries, "closing the technology gap" between these countries and more mature industrial nations is an important rationale of foresight programmes. That was also the rationale of the early Japanese foresight programmes in the 1960s. Some former centrally planned East European countries such as Hungary use their national foresight in building up a national system of innovation. In Germany and the UK, technology foresight programmes are now seen as tools for "wiring up" national systems of innovation. Although industrial competitiveness and the creation of new jobs and new business opportunities are key issues in foreign foresight programmes, individual research institutions, companies and especially SMEs' strategic possibilities and needs often arises as a second priority. As only large firms are able to carry out comprehensive in-house technology foresight projects, this leaves a need for developing and offering such strategic tools for Danish small and medium-size enterprises (or groups of these) as well as research institutions (meso- and micro-level foresight). Hence, methodologies for technology foresight in a Danish context must take its origin in the organisational levels of groups of firms or individual firms or research institutions. The traditional foresight methodologies of technology radar, Delphi surveys, expert panels and scenario processes will be utilised, but only in adapted versions.

Third, all firms, especially those that are small and medium–size, are widely dependent on changes in their technological environment and must prepare for future (externally originated) developments in that environment through a proactive strategy. That is why the literature on corporate strategy emphasises the use of technology radar, technology intelligence or technology scanning or what else this has been labelled. But the literature is sparse on how to perform such technology radar. Hence, an important element of technology foresight in Denmark will be the development and utilisation of such technology radar methodologies.

Fourth, Delphi-based methods (structured and iterative questionnaires) have been the "work-horse" of technology foresight programmes in many countries. The strength of Delphi surveys is that they allow the inclusion of a wide range of people in a foresight process. A weakness in a Danish context might be that many experts are fed up with questionnaires from all sorts of organisations. If Delphi surveys are to be important for Danish foresight studies they must have a clear objective to secure the engagement of the participants, and the participants must have a clear idea of "what's in it for me". Furthermore, the potentials of Internet and e-mail based Delphi questionnaires must be explored.

Fifth, preliminary studies indicates that the "work-horse" in technology foresight processes in future Danish foresights might be panels of stakeholders using scenario processes. A major challenge is to design processes that not only include the opinions and interests of elite scientists, industrialists, and policy makers as in most foreign foresight programmes, but also the opinions of employees, consumers and the general public.

Furthermore, as scenario processes are likely to become important in future technology foresight projects, the department in 1999 participated in a study with the main objective of establishing a scenario statement database. The study was carried out in collaboration between the Systems Analysis Department at Risø, Centre for Industry Analysis at Danish Technological Institute, Tele Danmark A/S and NKT Research Center A/S. The aim of the study was to create a comprehensive database consisting of numerous statements concerning the future. The database is hierarchically structured into a number of different categories covering a wide range of applications within societal, economic, environmental, political, and technical issues. The database is developed as a web-tool

with direct access for all participating companies. In the longer time-perspective, it is the intention to relate the different statements to graphical images. The participation of companies with widely different research fields and competencies makes it possible to develop a scenario-tool, which can be utilised for widespread applications. The idea is to use the database to develop the first draft of a new scenario. After searching specific themes the database will supply a range of related statements that might be used as basis for describing new scenarios. The main idea of having a scenario statement database is not only to provide the inspiration to produce new scenarios, but also to facilitate and speed up the normal scenario process, thus shortening the needed time and hopefully cutting down on the number of required meetings.

Per Dannemand Andersen and Poul Erik Morthorst

Prospective study of a genetically modified perennial ryegrass

In Europe genetically modified crops are met with uncertainty and scepticism and have only to a very limited extent found their way to the fields and the markets. In Denmark there is an increasing interest in food safety and there is a common attitude that the application of gene technology will reduce the quality of food and cause ecological disturbance. At the same time, the food producers are focusing on the benefits from the new technology. From their point of view the application of genetically modified crops will increase the food quality, reduce the production expenditures and in some cases give rise to environmental benefits.

Analysing the consequences of deliberately releasing genetically modified crops into the environment is a very complex task. From a societal perspective, it is therefore necessary to take a precautionary approach, as it remains important to ensure that new hazards are identified and appropriate measures implemented.

Approach

A technology foresight framework has been tested to analyse systematically the problems of the development and future marketing of genetically modified crops. The case studied was a joint research project between the producer of clover and grass seed, DLF-Trifolium A/S, and the Plant Biology and Biogeochemistry Department at Risø. The objective of the project is to produce a genetically modified form of ryegrass, which is incapable

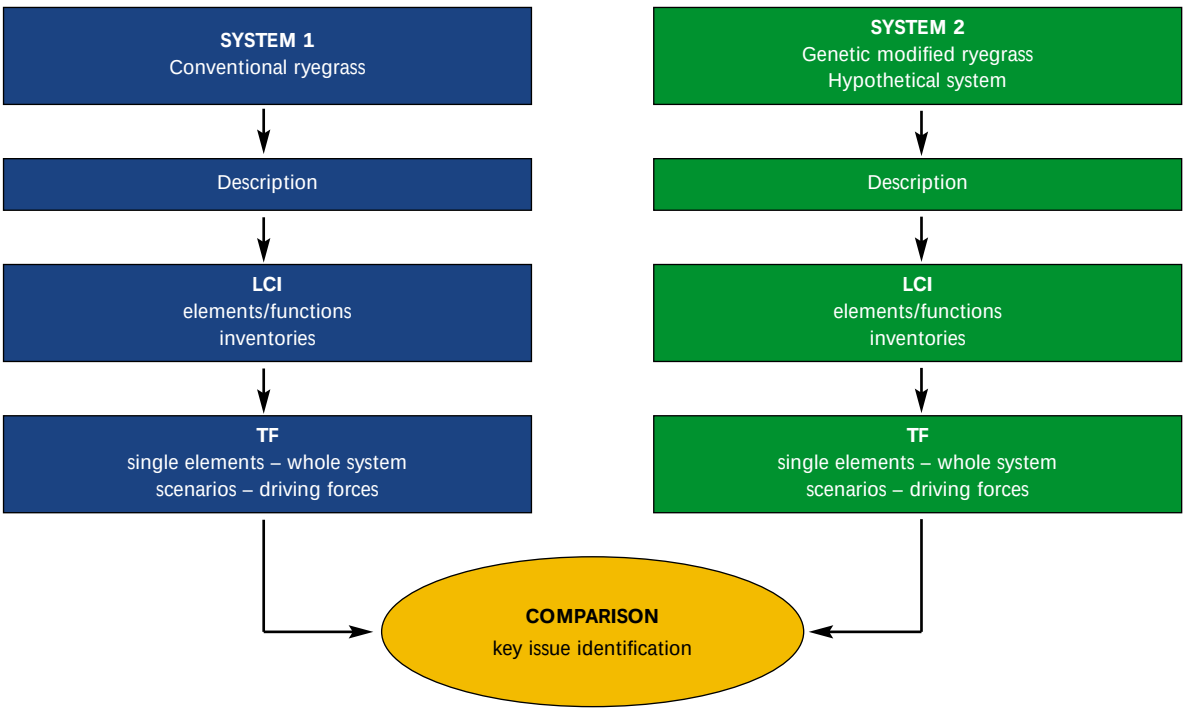


Figure 1. Technology foresight of ryegrass system

of producing stems and flowers during grassland farming.

The approach, which is indicated in the Figure 1, involved the comparison of a conventional perennial ryegrass system and a hypothetical system with genetically modified perennial ryegrass.

LCI (Life Cycle Inventory) is a frame to structure information and it recognises that all stages of a product life cycle have environmental, social, and economic impacts. The basis for the LCI is the determination of the functional units of the system and the starting and ending points of the life cycle. For a biological system the starting and ending points have to be defined arbitrary, as the life cycle of a biological system in principal has no start or end.

The LCI serves as the foundation for the TF analysis. As noted above, LCI is a frame to structure information. In this study, a conventional grass system was described qualitatively and visually, assisting the identification of principal differences between a conventional and a GM grass field system. The LCI, indicated in Figure 1, gave an overview of the grass field system and it identified a complicated network of stakeholders and experts that could be consulted later in the process. The main problem was to determine boundaries that limited the complexity of the system without losing the holistic perspective, and acquire sufficient information to give an adequate input to the scenario analysis.

Identifying experts per se is an important assignment if the analysis is to be a success, and in this study the LCI was an adequate tool for the purpose. The experts were representatives of key stakeholders. They need to have the ability to extend their substantive knowledge into the uncertainties of the future, and they have to be imaginative.

Scenario analyses have been successfully used in exploring options for future crop protection. The scenarios consider the wider implications of future decisions such as changes in the structure of industrial sectors, political decisions, consumer acceptance, substitute technologies, etc. In the process the inevitable/predetermined driving forces were distinguished from the uncertain ones and then ranked by importance and uncertainty.

Outcome

In a changing and unstable political environment it is important to have identified a number of scenarios to give the decision-makers the opportunity to monitor trends and be prepared for alternative developments in the market. The uncertainty interval of the uncertain driving forces can be used by decision makers to construct a number of scenarios with the objective to find strategies that perform well in all scenarios. From a corporate perspective, a trend scenario, which describes the development of the present from certain trends, is the most useful. From a more general perspective concerning the acceptance of genetically modified crops among consumers, the combined industry must collaborate with the authorities in developing threat and conflict scenarios (worst case scenarios), which can elaborate possible conflicts and their causes, making it possible to devise adequate countermeasures.

The overall experience from this exercise is that the technology foresight process assists a dialectical debate reducing the comprehensibility gap between different scientific disciplines and between different stakeholders, and securing the progress of the genetically modified crop technology. Finally, the study revealed the societal necessity to reach a consensus about coverage and application of risk assessment on the genetically modified crop technology.

Kristian Borch and Birgitte Rasmussen

Summary Statistics

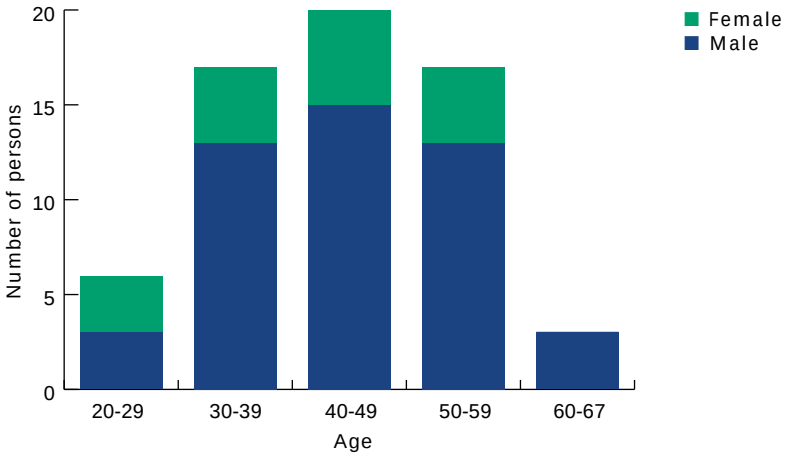
By the end of the year the total number of employees in the department was 63, of whom 16 were women and 47 men. More than 90 per cent of the staff have an academic background. The age distribution shows that approximately one third of the staff members are between 40 and 49 of age. One quarter are in the categories 30-39 years and 50-59 years respectively.

The total number of publications in 1999 amounted 122, slightly more than in 1997 and 1998. The number of international publications decreased from 52 in 1998 to 46 in 1999, while the number of conference contributions in proceedings rose from 40 to 50 in the same period. The number of publications in Danish journals has declined from 26 in 1997 to 17 in 1999.

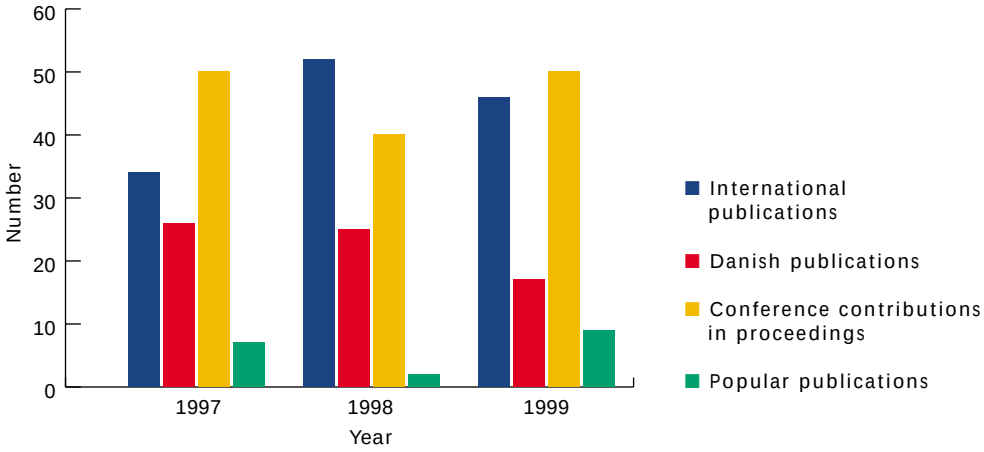
Staff 1999

	Females	Males	Total Staff
Academics:			
Head of Department and programmes	0	5	5
Research specialists	1	1	2
Senior scientists	4	25	29
Scientists	3	3	6
Technical/administrative staff	1	3	4
PhD students	2	6	8
Postdoc fellows	1	2	3
Technicians	0	2	2
Secretaries	4	0	4
Total staff	16	47	63

Age distribution

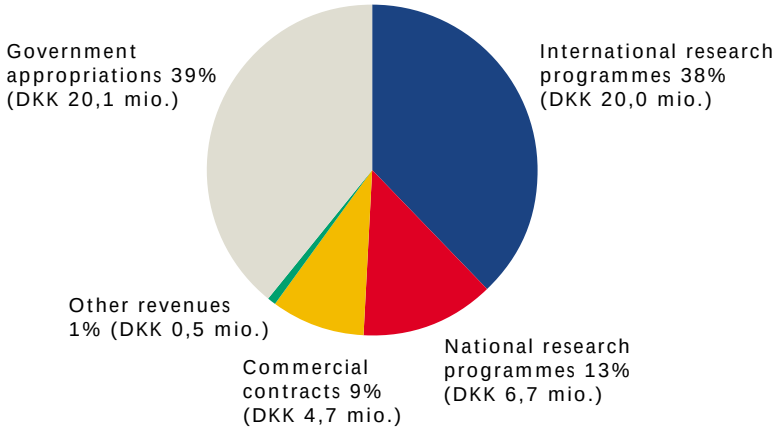


Publications

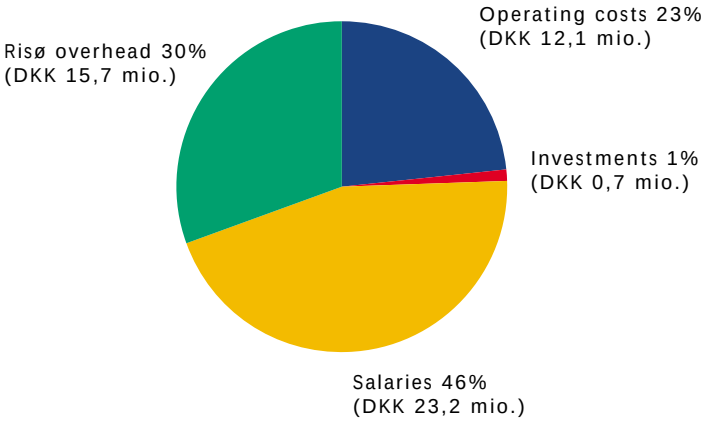


In 1999 total revenues amounted to DKK 52,0 mio. At the same time expenditures were DKK 51,7 mio. thus resulting in a minor surplus. 39 per cent of the revenues come from government appropriations and 38 per cent from international research programmes. Salaries account for 46 per cent of the expenditures while 30 per cent are Risø overhead.

Revenues



Expenditures



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Abstract
This report describes the work of the Systems Analysis Department at Risø National Laboratory during 1999. The department is undertaking research within Energy Systems Analysis, Energy, Environment and Development Planning - UNEP Centre, Safety, Realiability and Human Factors, and Technology Scenarios. The report includes summary statistics and lists of publications, committees and staff members.

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